PB-234 355

COKE CHARGING POLLUTION CONTROL DEMONSTRATION

AMERICAN IRON AND STEEL INSTITUTE

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY
JONES AND LAUGHLIN STEEL CORPORATION

MARCH 1974

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completi

1. REPORT NO.
EPA-650/2-74-022

2.

3. F
PB 234 355

4. TITLE AND SUBTITLE
Coke Charging Pollution Control Demonstration

5. REPORT DATE
March 1974

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
J.H. Stoltz

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Jones and Laughlin Steel Corp.
Pittsburgh, Pa. 15219

Contractor: American Iron and Steel Institute

10. PROGRAM ELEMENT NO.
1AB013; ROAP 21AFF-03

11. CONTRACT/GRANT NO.
CPA 70-162

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
NERC-RTP, Control Systems Laboratory
Research Triangle Park, N.C. 27711

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The report gives results of demonstrating a coke oven charging system designed to reduce emissions sufficiently to both meet future air pollution control requirements and improve the environment on top of the battery for operating personnel. The work included detailed engineering, construction, and testing of a prototype system on an existing battery with a single gas collecting main. The demonstration showed that, although emissions were reduced significantly, the system must be modified with a double gas off-take to satisfy air pollution control requirements. The system can be applied to new batteries or to existing batteries where a double gas off-take exists or can be obtained by such means as a second collecting main or jumper pipes. The battery top environment was improved for the larry car operator by having the charging sequence performed from within an air-conditioned cab. Although a lidman is required on the top side of the battery, his work conditions were improved by having the larry car perform lidding and dampering operations.

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U S Department of Commerce
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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Leveling	Air Pollution Control	13B
Iron and Steel Industry	Ovens	Stationary Sources	11F
Coking	Pressure Control	Coal Charging	13H
Metallurgical Fuels		Charging on Main	21D
Automation		Controlled Feed	13A
Feeders			

18. DISTRIBUTION STATEMENT
Unlimited

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
327

22. PRICE
$7.50- 1.45

i

EPA Form 2220-1 (9-73)

EPA-650/2-74-022

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by

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Pittsburgh, Pa. 15219

Contract No. CPA 70-162
ROAP No. 21AFF-03
Program Element No. 1AB013

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Control Systems Laboratory
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Research Triangle Park, North Carolina 27711

Prepared for

AMERICAN IRON AND STEEL INSTITUTE ✓
150 EAST 42nd STREET
NEW YORK, N. Y. 10017

and

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C. 20460

March 1974

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This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

CONTENTS

PAGE

List of Figures v

List of Tables viii

Acknowledgments ix

SECTIONS

I Conclusions 1

II Recommendations 11

III Introduction 15

IV The AISI/EPA Charging System 20

V Charging Equipment Description 30

VI Project Results - Smokeless Charging 69

VII Project Results - Process Control 90

VIII Project Results - Performance of Equipment 101

IX Application of System to New Batteries 172

X Application of System to Existing Batteries 181

XI Cost Data 186

XII Bibliography 196

XIII Glossary 198

XIV Conversion Factors 200

CONTENTS

SECTIONS		PAGE
XV	Appendices	201
	A. Oven Pressure Measurements	202
	B. Reliability Data	204
	C. Leveler Bar Investigation	224
	D. Emission Data	261
	E. Empty Oven Tests	283
	F. Battery Dimensional Variations	291
	G. Ascension Pipe Particulate Sampling	295

FIGURES

NO.		PAGE
1	Charging Emissions - AISI/EPA Car	2
2	Charging Emissions - Conventional Car	3
3	Emissions - Conventional Charging	16
4	Emissions - Conventional Charging	17
5	Charging System - Single Gas Off-Take	21
6	AISI/EPA Charging System Automation	22
7	AISI/EPA Larry Car	31
8	Cross-Section P-4 Battery	32
9	Coal Charging Car Arrangement	33
10	Coal Charging Car Arrangement	34
11	Drop Sleeve Feeder Operation	35
12	Automatic Lid Lifter	38
13	Place Oven On-The-Main	40
14	Oven Dampered-Off	41
15	Ascension Pipe Cleaner	43
16	Operation of Positioning System	45
17	Positioning System Arrangement	46
18	Lid Lifter and Drop Sleeve Hydraulic Panel	48
19	Environmental Unit Arrangement	50
20	Environmental Unit - Top View	51
21	Pusher- Charging Car Interlock	54
22	Carrier Current Signal System	56
23	Leveler Door Operator	60
24	Leveler Door	61
25	Existing P-4 Ascension Pipe	63
26	New Design Ascension Pipe	64
27	Self Cleaning Steam Nozzle	66
28	Charging Hole Lid	67
29	Butterfly Oscillation Angle	77
30	Coal Level Profile During Charging	80
31	Jumper Pipe Charging	84
32	Jumper Pipe Arrangement	85
33	Gravity Feed Hopper Test Arrangement	102
34	Drop Sleeve Seating	104
35	Hopper Fatigue Crack	106
36	Coal Level Sensor	115
37	Bent Steam Linkage Rod	123

FIGURES

(continued)

NO.		PAGE
38	Ascension Pipe Operating Linkage	125
39	Ascension Pipe Operating Linkage	126
40	Broken Standpipe Cap Hinge Lugs	127
41	Damper Stop Mechanism	129
42	Self Aligning Gooseneck Cleaner	132
43	Gooseneck Cleaner Operation Description	133
44	Positioning System Accuracy Data	136
45	Insulation of Proximity Switch	144
46	Open Web Leveler Bar	152
47	Leveler Bar Bulb Angle Cross-Section	155
48	Solid Web Leveler Bar	156
49	Wedge-Shaped Leveler Bar	157
50	Empty Oven Tests	162
51	Ascension Pipe Ejector Performance	164
52	Double-Piston Self-Cleaning Steam Nozzle	168
53	Ascension Pipe Elbow Covers	169
54	Oven Pressure Recording	203
55	Definition of Larry Car Availability	206
56	Definition of Larry Car Production Index	211
57	Larry Cars on P-4 Battery	212
58	Larry Car Performance Record	213
59	Larry Car Performance - Data Form	214
60	Larry Car Performance - 3 Months	215
61	Microstructure - Leveler Bar Steel	232
62	Leveler Bar Web	233
63	Leveler Bar Temperature Distribution	235
64	Leveler Bar Temperature Distribution	237
65	Leveler Bar in Coke Oven	238
66	Leveler Bar Thermocouple Locations	239
67	Thermocouple Switching Circuit	241
68	Leveler Bar Temperature	246
69	Leveler Bar Temperature	247
70	Leveler Bar Temperature	248
71	Leveler Bar Temperature	249
72	Leveler Bar Temperature	251

FIGURES

(continued)

NO.		PAGE
73	Leveler Bar Temperature Rise	252
74	Leveler Bar Heating Time	254
75	Orifice Flow Meter	284
76	P-4 Battery Dimensional Growth	292
77	Photomicrographs of Suspended Solids in Tar	298
78	Ascension Pipe Coal Carry-over Sampling	305
79	Coal Sampling Apparatus	306

TABLES

NO.		PAGE
1	Charging Emissions - Single Gas Off-Take	4
2	Charging Emissions - Jumper Pipe	6
3	Larry Car Charging Emissions	70
4	Larry Car Charging Emission Data	72
5	Charging Emissions, Variable Steam Pressure	74
6	Tar Samples P-4 Battery	95
7	Production Tar Analysis	96
8	Coke Oven Gas Analysis	98
9	Gum Content of Circulating Wash Oil	99
10	Larry Car Capital Costs	187
11	Pusher Machine Capital Costs	188
12	Battery Modification Capital Costs	189
13	Charging System Options	190
14	Leveler Bar Costs	191
15	Larry Car Maintenance Requirements	193
16	Other Charging Maintenance Requirements	194
17	Type of Larry Car Failures - December	216
18	Type of Larry Car Failures - January	217
18a	Type of Larry Car Failures - February	218
19	Larry Car Failures - January	219
20	Larry Car Maintenance - January	221
21	Operating Problems - January	223
22	Leveler Bar Chemical Analysis	230
23	Leveler Bar Mechanical Test Results	231
24	Partial Summary Leveler Bar Heat-Up Data	243
25	Regression Analysis - Final Leveling Bar Temperature	244
26	Summary of Leveler Bar Heat-Up Data	258
27	Leveler Bar Correlation Matrix for Midel	259
28	Distribution and Size of Suspended Solids in Tar	299

ACKNOWLEDGMENTS

It is not possible to acknowledge all the names of the many individuals who willingly gave of their time and made contributions to the project. Dr. T. E. Dancy* directed the early development work at J&L Steel involving J. J. Butler and J. P. Connolly. Engineering work by Koppers Company was the responsibility of S. P. Resko and L. G. Tucker.

Major contributions to this AISI program were made by members of the Joint Coordinating Group on Coke Plant Equipment under the Chairmanship of F. C. Lauer, Assistant Works Manager, Aliquippa Works, J&L Steel. This chairmanship is now held by J. G. Munson, Jr., U. S. Steel Corporation. Mr. R. L. Dobson, Wheeling-Pittsburgh Steel, as Chairman of the Technical Committee on Coke Oven Practice, was actively involved. The advice of W. M. Smith in the area of emission and environmental testing is acknowledged.

Dr. E. O. Kirkendall, Vice President, AISI, was the Project Director and responsible for all work performed on this contract with the Federal Government. The interests of the Environmental Protection Agency, in helping with the development of a smokeless charging system, were represented by N. Plaks and R. V. Hendriks.

The project at Jones & Laughlin was under the management of W. G. Ulevich. Test work at P-4 Battery involved the close cooperation of the By-Product Department and the help given by T. R. Greer, Superintendent, was appreciated. The direct supervision of the work on P-4 Battery was the responsibility of J. R. Lee whose many contributions helped bring about an operable system. He was succeeded by T. G. Szczepanski, whose oven experience was utilized in solving operating system problems.

Particular thanks are due J&L personnel L. J. Tyrrell, Maintenance; A. A. Mammarelli, Environmental Control; E. C. Renninger and G. W. Kiefer, Operations; J. L. Kiefer, Chief Chemist; J. L. Sundholm and R. W. Helm, Engineering; C. E. Barth, Electrical Maintenance; N. C. DeLuca, E. A. Mizikar, L. S. Pope, and R. M. Patalsky, Research; and B. A. Zemke, Development Engineering.

* T. E. Dancy Now with Sidbec - Dosco, Montreal, Canada

The work done on this system would not have been possible without the engineering by Koppers Company. This portion of the project was managed by W. D. Edgar. The work of Koppers engineers H. R. Bartlebaugh, larry car design, and E. C. Hetrick is acknowledged.

The larry car cab and control room and the electrical system were furnished by General Electric.

And a final note of appreciation is due Jane Mattes, who typed the many required reports in addition to this final one. Milan Mrkobrad made all the sketches.

The work upon which this publication is based was performed pursuant to Contract No. CPA-70-162 with the Environmental Protection Agency.

J. H. Stoltz
Project Supervisor

SECTION I

CONCLUSIONS

A full scale demonstration of a coke oven charging system designed to meet future air pollution standards was engineered, built, installed, and tested on an existing battery with a single gas collecting main. A one year test program was included to permit design modifications to be made where necessary to improve system reliability. Specific test procedures were used in making an evaluation of the charging emissions and equipment reliability.

CHARGING EMISSIONS

The system was to reduce emissions sufficiently to meet future air pollution control regulations. The quantitative evaluation of emissions was determined visually according to the number of seconds the charging emissions correspond to a given Ringelmann number or equivalent opacity.

After a year's operation, it can be concluded that the present system has resulted in a significant reduction in emissions during charging when compared with the results using conventional charging cars at P-4 battery. A direct comparison of results can be made from Figure 1 which shows average emissions from the new P-5 larry car. Similar data for the P-3 conventional table feed larry car is shown on Figure 2. The data, taken by the emission control engineer, is presented in terms of opacity.

In spite of this improvement, the average charging emissions have not been reduced to a level that will meet the minimum acceptable criteria for this project, nor will they meet the local air pollution control regulations now applicable to P-4 battery. Table 1 compares the emissions which occur during charging with the various air pollution criteria. The emission data presented represents the best results that can be reasonably expected when all components are functioning properly.

There have been a few smokeless charges made with this system, but they represent the exception to normal performance. It has not been possible to make smokeless charges consistently

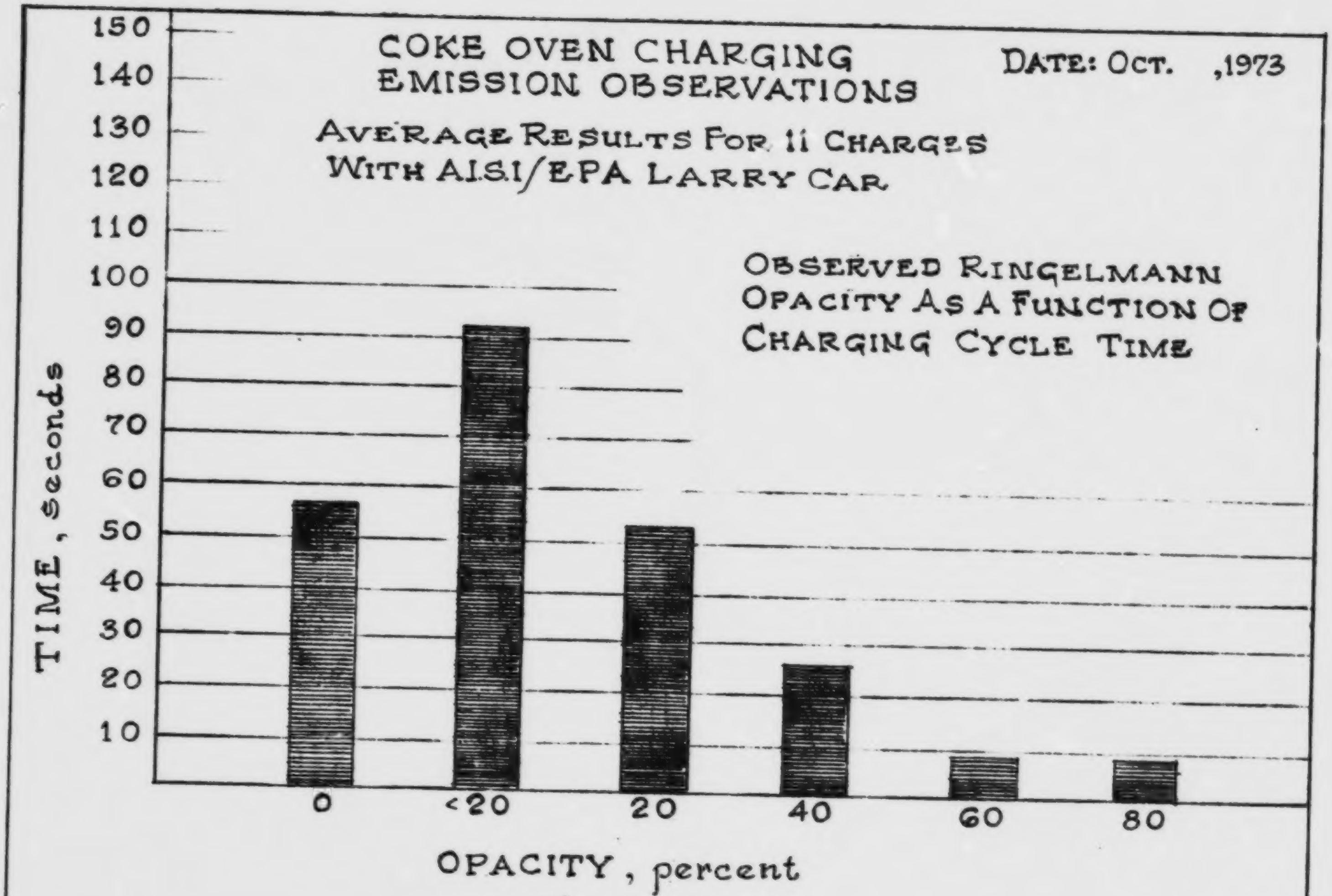

COKE OVEN CHARGING
EMISSION OBSERVATIONS
DATE: OCT. ,1973
AVERAGE RESULTS FOR 11 CHARGES
WITH A.I.S.I/EPA LARRY CAR
OBSERVED RINGELMANN
OPACITY AS A FUNCTION OF
CHARGING CYCLE TIME
TIME, seconds
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
<20
20
40
60
80
OPACITY, percent

Figure 1

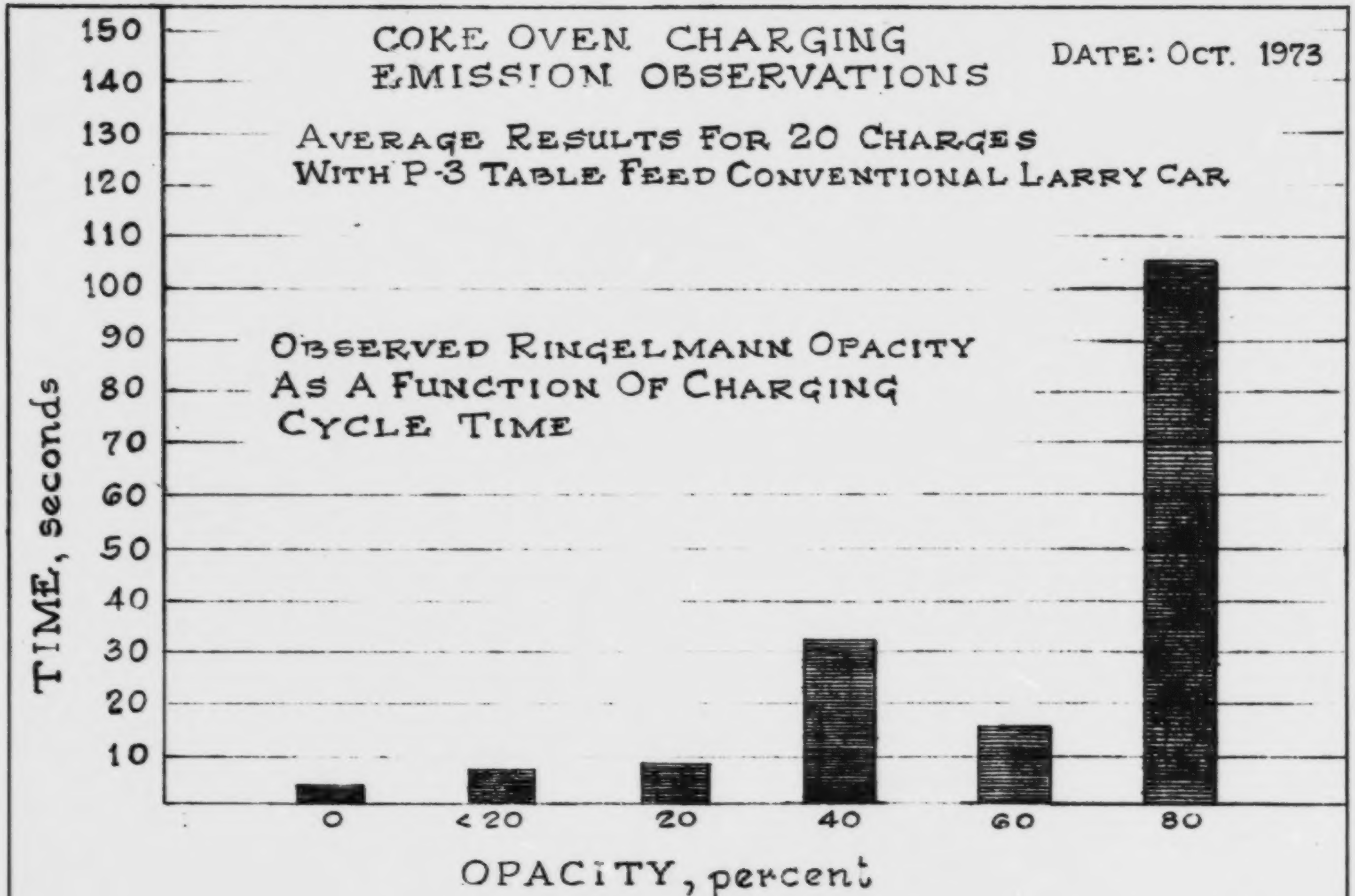

COKE OVEN CHARGING
EMISSION OBSERVATIONS
DATE: OCT. 1973
AVERAGE RESULTS FOR 20 CHARGES
WITH P-3 TABLE FEED CONVENTIONAL LARRY CAR
OBSERVED RINGELMANN OPACITY
AS A FUNCTION OF CHARGING
CYCLE TIME
TIME, seconds
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
< 20
20
40
60
80
OPACITY, percent

Figure 2

Table 1. LARRY CAR CHARGING EMISSIONS COMPARED WITH VARIOUS ACCEPTABLE CRITERIA

(Single gas off-take)

Measured Parameter Seconds	5 Charges December 1973	Minimum Acceptable Criteria for Project	Local Air Pollution Regulations
Avg. charge cycle time	258.6	X[a]	X
Avg. T0	68.8	X	X
Avg. T1	85.6	X	X
Avg. T2	71.0	≤ 108[b]	0
Avg. T3	37.0	≤ 36	0

a. X - No limiting value.

b. Criteria values are based on 5 charges per hour.

Charge Cycle Time = Interval from start of coal charge till re-lidding complete.

T0 = Number of seconds no smoke.

T1 = Number of seconds in which smoke opacity is less than 20% (Ringelmann #1) but greater than T0.

T2 = Number of seconds in which smoke opacity is less than 40% (Ringelmann #2) but greater than T1.

T3 = Number of seconds in which smoke opacity is equal or greater than 40% (Ringelmann #2) because during leveling there is no way to assure an open gas passage at the top of the oven with a single gas off-take.

ACHIEVEMENT OF SMOKELESS CHARGING

To approach smokeless charging conditions (any and all smoke less than 20% opacity), it is necessary that the system be modified by the addition of a second gas off-take at each oven. As described in the section on Project Results (pg 81), the addition of a "jumper pipe" connecting the extra coke side smoke hole on one pair of ovens was used to observe the effect of a double gas off-take. The results of fifteen charges using jumper pipes, shown in Table 2, can be compared with the results in using a single gas off-take in Table 1.

Emissions equal to or exceeding 20% opacity occurred for an average of 8.4 seconds per charge. It may be possible to reduce this average value somewhat as additional experience is gained in the use of jumper pipes.

BY PRODUCT SYSTEM

At this time, any adverse effects of this charging system on the By-Products appears to be minimal. Since the raw gas from five batteries make up the by-products, it is difficult to isolate the effects of this charging system from the whole. During the past year there has been no significant change in the quality of the tar.

The following changes have occurred that may be attributed to the installation of "jumper pipes" on the other four batteries as well as the effect of this charging system on P-4 battery.

Table 2. LARRY CAR CHARGING EMISSIONS USING A JUMPER PIPE

(Double gas off-take)

Measured Parameter Seconds	15 Charges January-March 1974	Smokeless Charging
Avg. charge cycle time	219.5	X
Avg. T0	197.6	X
Avg. T1	13.5	X
Avg. T2	4.0	0
Avg. T3	4.4	0

Definition of Terms Shown Below Table 1.

BY-PRODUCT SYSTEM (continued)

1. The air content of the coke oven gas has increased somewhat (20%) as evidenced by an increase in nitrogen.

2. The sludge taken from the flushing liquor decanter tanks has increased about 15% during the past year.

3. The frequency at which condensate drains requires cleaning has increased in the past year, and the drain tar is heavier. This is noticable at the primary cooler, the gas exhauster, the tar extractor, and the gas booster (compressor).

4. The result of accidentally leaving the aspirating steam on several ovens (beyond the charging requirements) is to increase the volume of coke oven gas. An excessive increase in gas will overload the primary cooler causing an increase in the temperature of the gas. This results in a corresponding increase in gas volume which, if of sufficient magnitude, can reach the limit of the gas exhauster. This causes increased back pressure that will decrease the oven suction.

None of these effects represents a significant problem at this time.

CHARGING EQUIPMENT RELIABILITY

The coal charging car and associated equipment was to achieve sufficient reliability so as to be available for satisfactory production operation 90% of the total scheduled operating time. The larry car availability measured over a three-month period was 86.0%. The two principal factors which limit the reliability are:

1. Failure of hydraulic equipment, sensors, and wiring principally as a result of burning gases under pressure.

2. Failure of wet coal to reliably discharge from the hopper drop sleeves.

IMPROVE WORKER ENVIRONMENT ON TOP OF BATTERY

The environment on top of the battery was to be improved for operating personnel. The charging equipment was mechanized and automated so that normal duties of the charging car operator could be performed from within the controlled environment of an enclosed cab. By incorporating the functions of lidding, dampering, and steam aspirating into the larry car operation, it was hoped that there would be no need for continually exposing any operating personnel to the top side battery environment. The opening and closing of the leveler door was mechanized so that the pusherman could operate the door from within the pusher cab, and avoid exposure to oven flames.

Charging Car Operator's Environment

The top battery environment of the charging car operator has been considerably improved as a result of initiating sequences from within an air conditioned cab.

At the present time there are three occasions for the operator to leave the cab.

1. Cleans gooseneck with manual swab.

2. After placing oven on-the-main, he usually inspects ascension pipe linkage to determine proper operation.

3. If problem arises with coal feed, he leaves cab to look inside hoppers, and, if necessary, he leaves the car to start coal flow with a steel rod at the drop sleeves.

Manual cleaning of the gooseneck will no longer be required if the remotely operated cleaner becomes fully operational. The inspection of ascension pipe linkages takes only a few seconds and represents no serious exposure. The problem of coal feed represents the most severe shortcoming. With wet coal conditions this problem may occur on about 10% of the charges. The operator's time outside the cab on the battery averages less than 15% of the total, thus representing a significant reduction in exposure. If improvements in the coal feed system are achieved, this figure can be cut in half.

Lidman's Environment

The dimensional variations of the standpipes with respect to the larry car position has limited the reliability of the mechanized damper and steam aspirating system. The lidman operates the linkages on those ovens where satisfactory mechanized operation has not been attained. The performance of the lid lifters has been satisfactory and has virtually eliminated the worst task of lidding. However there are a few times when manual lidding must be performed even though the mechanical lidding is reliable and working. The lidman must perform additional tasks which include sealing of oven ports when necessary.

When jumper pipes are installed on this battery, it will be necessary for the lidman to manually operate the jumper pipe valve and control the aspirating steam valves. Operation of the damper and ascension pipe lid will be done by the larry car, utilizing the lidman only in case of a malfunction.

The exposure of the lidman to emissions has been significantly reduced as a result of improving charging performance, and the use of a lid lifter.

Pusherman's Environment

The use of a mechanized leveler door operator has improved the pusherman's environment as a result of operating the doors from within the cab. He now opens the door manually only in case of occasional equipment malfunction.

AUTOMATIC CHARGING

The larry car operator was provided with two methods for controlling the coal charging process. The automatic mode initiated operations according to pre-determined sequential criteria. The manual mode of charging was accomplished by initiating individual sequences under the operator's direction.

The automatic sequence was not used extensively. The principal problem was related to its basic design which required successful completion of a given sequence prior to initiating

AUTOMATIC CHARGING (continued)

the next step. If a sub-operation was not completed, it was necessary to switch to the manual mode in order to continue.

An example is the failure of coal to flow from one of the drop sleeves. Under these conditions the operator closes the butterfly valves of the unaffected hoppers, and uses a bar to initiate proper coal flow. He then opens all butterfly valves and resumes normal charging. This type of problem occurs with sufficient frequency that makes it impractical to use the automatic mode.

The automatic system did work when the charging equipment performed as designed. The signal system between the larry car and the pusher machine functioned properly, but the wayside loop at the pusher machine would require relocation away from exposure to flame to achieve acceptable reliability.

The manual mode used in charging has sufficient flexibility and reliability to enable an operator to use it with confidence. The use of this manual mode appears to be an acceptable means of charging ovens.

ENVIRONMENTAL CONTROL UNIT

The air in the larry car cab and control room was conditioned by an environmental control unit. This unit was designed to remove particulates and harmful concentrations of coal tar pitch volatiles, SO_2, H_2S, and CO from the incoming air. It also controlled the air temperature.

The unit does provide the larry car operator with an improved environment. It has been expensive to maintain and it failed to meet the specifications for removal of particulates, coal tar pitch volatiles, and CO.

SECTION II

RECOMMENDATIONS

SMOKELESS CHARGING

As a result of extensive test work on the single gas off-take system, and observations using the double gas off-take (jumper pipes), it is recommended that a double gas off-take be used so that an open gas passage at the top of the oven can be maintained at all times during charging. This second gas off-take can take the form of an additional gas collecting main or some form of a jumper pipe (breeches pipe) arrangement.

IMPROVED SYSTEM OPERATION AND RELIABILITY

There are two steps that must be taken to realize significant improvements in the operation and reliability of this charging system.

1. Addition of second gas off-take

2. Improved coal feed system

The second gas off-take will minimize the incidence of hot burning gases during charging which damage hydraulic hoses and electrical wiring and sensors.

It also relaxes the requirements of the coal feed system. It is no longer necessary that the coal feed rates be closely controlled. It is required that the coal flow be reliable. Reliable coal feed is possible from either a forced feed system (table or screw feed) or a properly designed gravity feed system.

With regards to this particular larry car gravity feed system, improved coal feed can be obtained by either of two possible solutions.

1. Redesign the present gravity feed system

2. Change to a table feed system

IMPROVED SYSTEM OPERATION AND RELIABILITY (continued)

The less costly alternate of redesigning the present gravity feed system is preferred, if this can be successfully accomplished. Since the necessary redesign may involve only a modification of the drop sleeve, without affecting the hydraulic or electrical systems, this alternate solution will be given a first trial. The change to a table feeder system would represent a major undertaking.

The addition of the jumper pipes and the accomplishment of a reliable coal feed system is expected to result in a larry car availability of about 95%.

There are several general considerations that can be followed to improve the over-all system reliability:

1. Design mechanical equipment that will function properly with the large dimensional variations that exist on a battery.

2. Decrease the exposure of electrical equipment to the battery environment by minimizing the number of sensors and length of conduit runs, and adequately protecting required sensors.

3. Reduce hydraulic leakage by minimizing and shortening hose lengths.

IMPROVED WORKER ENVIRONMENT

It does not appear feasible to eliminate the need for exposure of operating personnel to the top side battery environment. Even if the larry car performed all functions of lidding, dampering, and steam aspirating, the following tasks would still be required.

1. Maintain cleanliness on the battery top

2. Remove carbon from charging holes and standpipes

3. Wet seal oven ports as required

4. Watch for malfunctions

IMPROVED WORKER ENVIRONMENT (continued)

It must be recognized that the top battery environment is being continually improved not only from smokeless charging, but also from reduced door leakage and improved pushing techniques.

AUTOMATION FOR COKE OVEN CHARGING

A large amount of automation was provided for this prototype system to accomplish two principal purposes:

1. Charge ovens in a controlled sequence that would minimize emissions.
2. Remove operating personnel from continual exposure to the top battery environment.

It is now apparent that smokeless charging can be accomplished on a modified system under the control of an operator using the manual operating mode. It is doubtful if the need for a lidman could be eliminated with a working automatic system.

The use of an automatic system requires for successful performance:

1. Reliable operation of all mechanized equipment so that the automatic system can remain in continual operation.
2. Trained technicians that will maintain it in operation.
3. Return on investment by improved results.

The two objectives which prompted the selection of an automatic system have almost been as substantially satisfied by the present manual operating mode as would be possible with a working automatic system. It seems unlikely that a reasonable return would be possible using an automatic system, and consequently its use is not recommended.

APPLICATION TO NEW OR EXISTING BATTERIES

The application of this modified charging system can be considered

APPLICATION TO NEW OR EXISTING BATTERIES (continued)

for use on new or existing batteries where a double gas off-take exists or can be provided.

SECTION III

INTRODUCTION

Metallurgical coke, used in blast furnace iron production, is made in slot type ovens by the controlled heating of coal. The coal is poured into hot ovens through charging holes from coal hoppers of a larry car that travels on rails over the top of the battery. Charging emissions, consisting of hot gases and particulates, result from the release of volatile matter within the coal. The use of steam jets in the ascension pipes connecting the oven to the raw gas collecting main helps direct most of the charging emissions into the closed by-product system. This is known as charging on-the-main. Not all the emissions are directed into the gas collecting main and a significant portion are released to the atmosphere through open charging holes and empty feed hoppers (Figure 3, 4). Additional emissions occur during the coking cycle as a result of door leakage and when the coke is finally pushed from the oven and quenched. Estimates indicate that charging emissions represent 50-60% of the total. Coke oven air pollution is a source of concern to the community as well as industry.

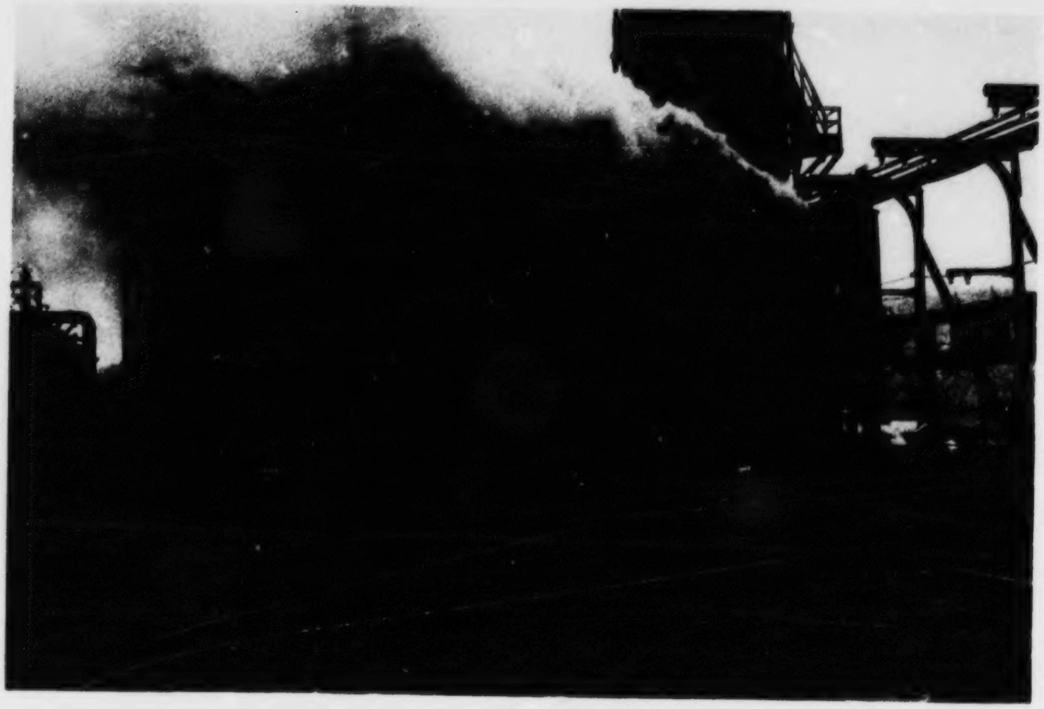
PROJECT - CONTROL CHARGING EMISSIONS

The American Iron and Steel Institute has made studies over a number of years addressed to the environmental health problems associated with coke oven emissions. The results of these early studies led most steel companies to initiate programs related to control of coke oven emissions.

In 1967 Jones & Laughlin started development work on a charging system that would meet future air pollution control standards. The results of this investigation favored the concept of controlling the flow of oven gases and particulates generated during charging so that they preferentially enter the gas collecting main. This technique was not new. Development of this method had been reported at batteries in England[3], Germany[4], and the Soviet Union[5].

This concept was discussed with the AISI Joint Coordinating Group on Coke Plant Equipment which had been conducting an independent investigation into improved charging methods. This committee had concluded that the concept of using gas cleaning equipment on the charging car was not likely to achieve an acceptable level of

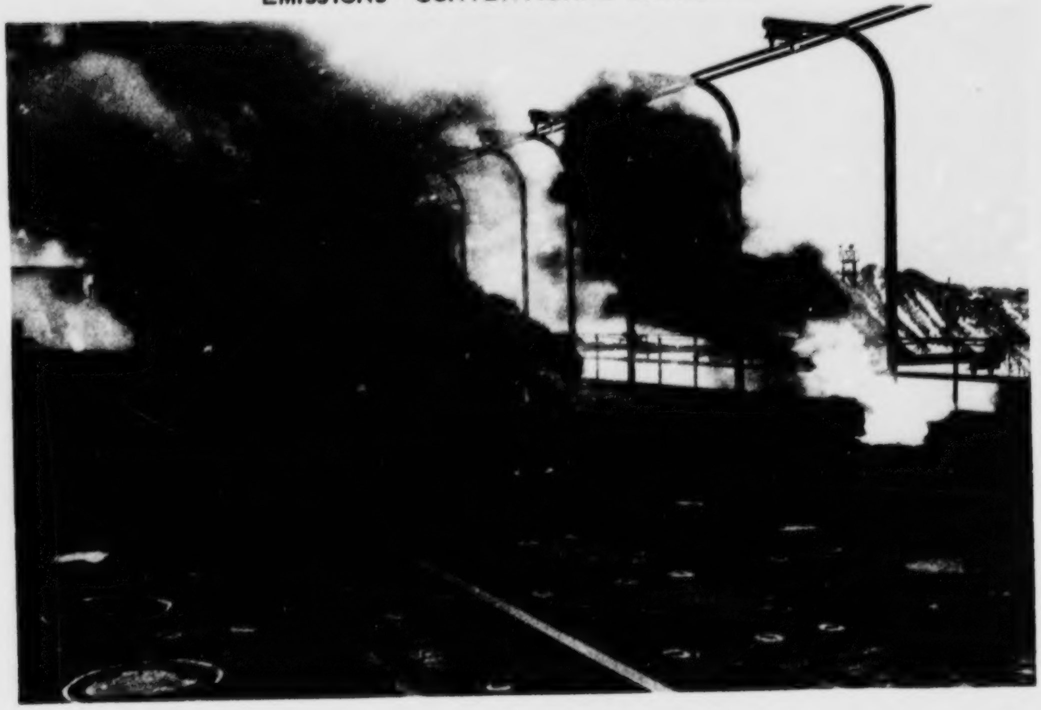
EMISSIONS - CONVENTIONAL CHARGING



CHARGING OVEN WITH CONVENTIONAL
GRAVITY FEED LARRY CAR

FIGURE 3

EMISSIONS - CONVENTIONAL CHARGING



OVEN TO BE RELIDDED AFTER
CHARGING COAL WITH LARRY CAR

FIGURE 4

PROJECT - CONTROL CHARGING EMISSIONS (continued)

air quality. The AISI accordingly decided to support development of an oven charging system based on controlling oven pressure. In March, 1969 a contract was signed whereby Jones & Laughlin Steel Corporation would manage the AISI coke oven charging study, with engineering work performed by Koppers Company.

A general specification was prepared which outlined the requirements of the new charging system. The equipment necessary to build a prototype production model was described. Test programs were set up for equipment evaluation.

In 1970 the AISI recommended joint sponsorship of construction and testing a full-scale production prototype coke oven charging system at P-4 Battery of the Jones & Laughlin Pittsburgh Works. Negotiations with the United States Government represented by the Environmental Protection Agency resulted in a contract being signed effective June 30, 1970. Under the terms of this agreement the government shares half the cost of this project with the AISI. Upon completion of the production prototype testing Jones & Laughlin will reimburse the AISI and the U.S. Government in accordance with the depreciated value of the economically operable equipment.

PROJECT GOALS

The object of this program was to demonstrate a full-scale operable charging system with the following features:

1. The system was to perform reliably and achieve a significant reduction in charging emissions. It was to have no adverse affect on the by-products.

2. The environment on top of the battery was to be improved for operating personnel. The equipment was to be mechanized and automated so that normal operations could be performed from within an enclosed cab, thus eliminating the need for continual exposure of operating personnel to the top side battery environment.

Production testing was required to determine the extent to

PROJECT GOALS (continued)

which project goals were achieved, and to make necessary equipment changes for the realization of these goals. This work was performed according to an organized plan which outlined the type of testing intended to establish the reliability of the larry car and associated charging equipment. Criteria were established for judging the success in reducing charging emissions.

PROJECT COSTS

The total appropriation was $1,877,040.00. The project was completed within that cost.

SECTION IV

AISI/EPA COAL CHARGING SYSTEM

CONCEPT

In concept the AISI/EPA Coal Charging System[1] eliminates emissions during charging by causing all the oven gases to pass through the ascension pipe into the gas collecting main (Figure 5). This requires the use of an ascension pipe steam ejector that is capable of delivering a volume of gas equal to that being generated and displaced during charging. The resulting low pressure (atmospheric or slight vacuum) creates a tendency at oven ports for air to be drawn into the oven.

This oven pressure control concept requires, as an essential part of the system, that all oven ports be sealed. During charging the leakage of air into the ovens must be limited so as not to significantly affect the quantity and quality of raw gas entering the collecting main particularly with respect to safe levels of oxygen. If during any part of the charging cycle, the quantity of gases generated exceeds the capacity of the ascension pipe steam ejector, emissions during the short interval would not be significant. A passage across the top of the oven to the ascension pipe must be assured to permit free flow of gases, thus minimizing pressure build-up. These conditions must be satisfied with a suitably controlled coal feed and leveler bar operation. At the end of coal charging, the equipment for sealing oven ports is retracted sequentially as required to prevent emissions.

CHARGING EQUIPMENT

The components provided for this system are shown in Figure 6. The equipment consists primarily of a new larry car, modifications to an existing pusher machine, and additions to the battery.

Gravity Feed Coal Charging Car

A gravity feed system was selected for this car. A drop sleeve underneath each hopper is lowered to seat within the charging hole ring prior to charging coal into the oven. A butterfly valve at

COKE OVEN CHARGING SYSTEM
SINGLE GAS OFF-TAKE

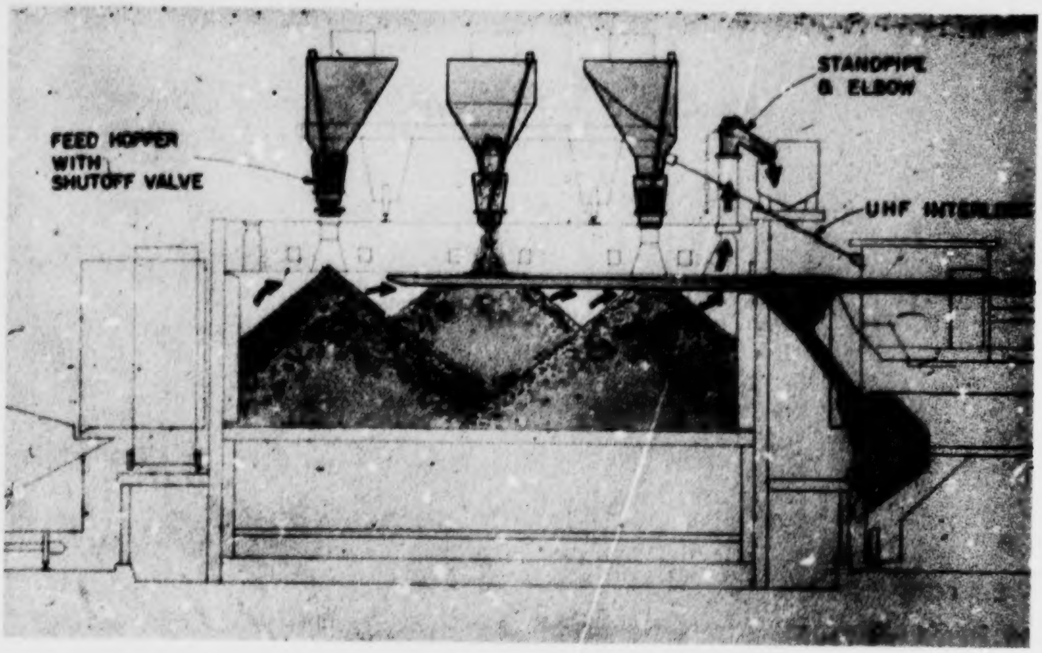
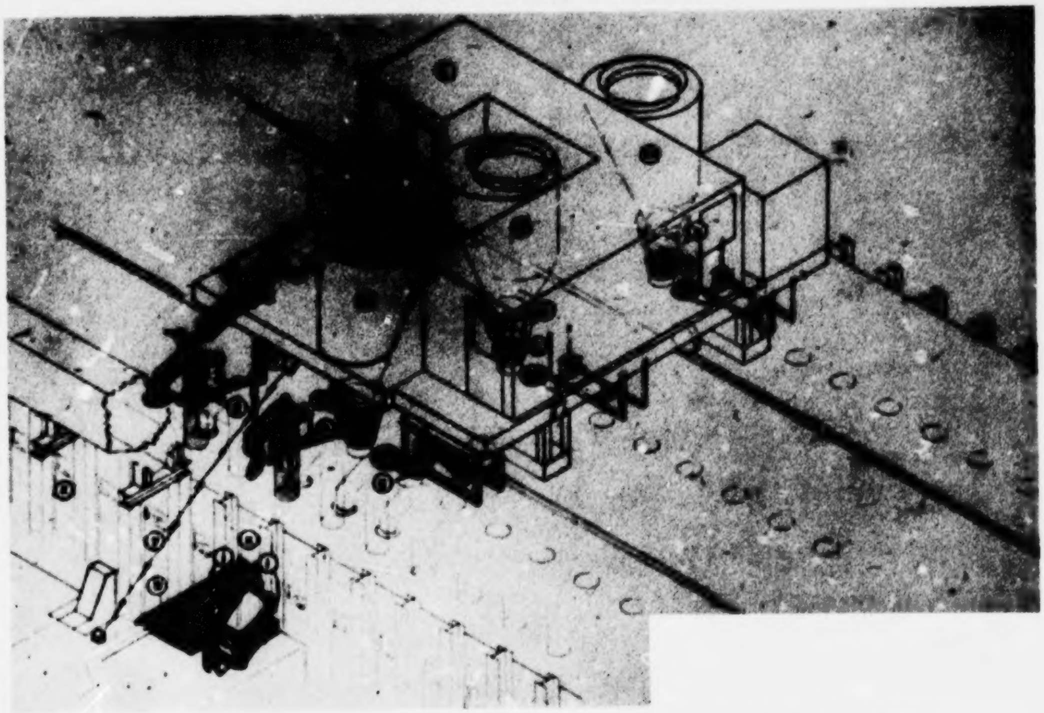

STANDPIPE
& ELBOW
FEED HOPPER
WITH
SHUTOFF VALVE
UHF INTERL

FIGURE 5

AISI CHARGING SYSTEM AUTOMATION



b. LEVELER BAR	i. LEVELER DOOR OPERATOR
c. UHF ALIGNMENT DEVICE	j. LEVELER DOOR SMOKE SEAL
d. ASCENSION PIPE DAMPER ACTUATOR	k. BUTTERFLY VALVES
e. GOOSENECK CLEANER	l. CONTROLLED ENVIRONMENT CAB
f. ASCENSION PIPE ACTUATOR (PLACE OVEN-ON-MAIN)	m. COAL HOPPER
	x. OVEN TO BE CHARGED
g. LID LIFTERS	y. OVEN TO BE PUSHED
h. FEED HOPPER DROP SLEEVES	z. OVEN TO BE DAMPERED-OFF

FIGURE 6

Gravity Feed Coal Charging Car (continued)

the bottom of the drop sleeve is oscillated to control the rate of coal feed. Coal level sensors determine the initiation of leveling and the final termination of coal feed. Sufficient coal is left in the drop sleeve to form a coal seal.

Mechanized lid lifters remove and replace lids. The operation of the ascension pipe damper valve, standpipe cap, and steam valve is controlled from the larry car by the operation of two rotary actuated levers. One lever raises to place the oven on-the-main by turning on aspirating steam, opening the damper, and closing the cap. The other lever lowers to damper off the oven by closing the damper valve and opening the stand pipe cap. A remotely operated car mounted gooseneck cleaner, with motor driven flails, cleans the gooseneck and return bend as it moves through the standpipe inspection port.

This equipment is powered from a central hydraulic system. Movement of the various mechanisms must be related to the larry car position on the battery with respect to a given oven. An automatic positioning system was furnished to accurately stop the car at the proper oven charging reference position. A special UHF interlock system was provided to assure that the pusher machine and the charging car were aligned on the same oven prior to charging.

The car was designed so that all charging operations could be initiated by the operator from within an enclosed cab. An environmental control unit furnishes clean temperature controlled air.

The operator was provided with an automatic and a manual means of charging ovens. The automatic mode ensured that a definite sequence was followed during charging to minimize emissions. The manual mode, under the control of the operator, did not require any control signal interlocks with the pusher machine.

Pusher Machine Equipment

The necessary modifications to the existing P-4 pusher machine

Pusher Machine Equipment (continued)

included the relocation of the leveler bar with respect to the pusher ram so that ovens could normally be pushed and charged without moving the pusher machine. A new light weight self-supporting leveler bar was provided so that leveling could be initiated shortly after the start of charging. A smoke seal around the leveler bar seals the door opening during charging.

A mechanized leveler door operator permits the pusherman to close and open doors from within the cab.

Battery Modifications

The required steam aspirating performance necessitated the use of high pressure steam. Accordingly a new steam line was built with provisions for regulating pressure. Self cleaning steam nozzles were provided to assure the maintenance of a properly directed steam jet. Five new goosenecks were installed having improved gas flow characteristics. A corresponding increase in gas flow through the existing goosenecks was obtained by increasing the steam nozzle size.

The addition of linkages at each ascension pipe was required to permit remote operation of the damper valve, standpipe cap, and steam valve. It was necessary to relocate charging hole rings to permit proper seating of the larry car drop sleeves.

Panels with brass vanes were mounted at each oven for the larry car positioning system. It was necessary to reinforce the collector rail supports on which they were mounted. Other portions of the battery were reinforced to hold the additional weight of the larry car.

A way-side loop antenna was installed the length of the battery for the larry car, and one for the pusher machine, as required by the signal system.

AUTOMATIC CHARGING SEQUENCE

A complete charging sequence in the AUTOMATIC mode will describe the original intended operating procedure by reference to Figure 6.

1. The car hoppers are filled with a specific coal volume determined by the measuring sleeve setting on each hopper.

2. The car is manually moved to within one oven space north of the next oven to be charged (x).

3. At about the same time, the pusher machine operator removes the pusher side door from the next oven to be pushed (y) and then positions the machine for single spot pushing and leveling (the oven to be pushed is two ovens south of the one to be charged).

4. Normally the leveler door will be open and the pusher operator will advance the leveler bar (b) until the leveler boot seal (j) is positioned over the door opening. This results in a signal to the coal charging car indicating "leveler boot extended".

5. Meanwhile the charging car operator actuates the AUTO CHARGE pushbutton.

   The car will automatically move south and stop within ± 0.35" of the oven to be charged.

   a. Normally the lids of the oven to be charged will have been removed. If the pusher machine operator had not previously brought the leveler boot seal to the oven (step 4) the oven lids are replaced so that the butterfly valves (k) are not exposed to the oven heat while waiting.

      The ascension pipe cleaner (d) removes carbon from the standpipe located two ovens south of the one to be charged. The cycle is then halted until the leveler boot is extended.

   b. With the leveler boot extended an alignment check is made to determine that the two machines are ready to charge the

AUTOMATIC CHARGING SEQUENCE (continued)

b. (continued)
same oven. A UHF transmitted signal (c) from the pusher is detected by the receiver on the charging car.

6. With an affirmative alignment check, three simultaneous operations are initiated.

    a. The lids that remain on the oven charging holes are removed by automatic lid lifters (g) and set down on the battery. After these lids are removed, the feed hopper drop sleeves (h) are lowered down over the charging hole to seal the openings.

    b. A rotary actuator on the car operates the ascension pipe linkage (f) so that the steam is turned on, the ascension pipe cap is closed, and the damper valve is opened.

    c. If the gooseneck (two ovens south) had not been previously cleaned, (step 5-a), this is done now.

7. The previous steps complete the preparations required prior to the actual coal charging. When all these operations have been completed, the three hopper butterfly valves open and start oscillating (k). This can be done simultaneously or with selective time delay. When a level sensor detects that 75% of the hopper coal load has been charged into the oven, the butterfly valve is closed. After all three butterfly valves are closed, a request is transmitted to the pusher to start leveling.

8. As soon as the first butterfly valve closes (100% coal charge), the re-lid cycle starts. Charging hole lids are replaced sequentially in the order of closing so that only one open charging hole can exist at one time.

9. When all three butterfly valves are closed, a request is made to the pusher to start the final leveling pass. This causes the leveler bar to make one complete final pass and retract to a point just inside the leveler door.

AUTOMATIC CHARGING SEQUENCE (continued)

10. After the re-lid operation is complete, the pusher machine is requested to retract the leveler bar. The pusher operator then actuates a pushbutton which causes the automatic leveler door actuator to close and latch the leveler door.

11. Upon receiving a signal that the leveler door is closed and latched, the ascension pipe steam valve is closed and the charging cycle is complete.

12. The operator then manually traverses the car almost two oven spaces south and actuates the REMOVE LID pushbutton. This causes the charging car to spot on the oven that just was or is now to be pushed (located two spaces south of the one just charged).

13. After the car is spotted the lid lifters remove one or more pre-selected lids so that decarbonizing of the charging holes takes place.

14. The car also closes the damper and opens the ascension pipe lid on the oven four spaces south of the one just charged (Z). This results in decarbonizing of the standpipe. The operator then returns to the coal bin and the total cycle is completed.

MANUAL CHARGING SEQUENCE

The manual mode permits considerable flexibility in the charging sequence. There are no control interlocks between the larry car and pusher machine. A voice communication system permits the operator to coordinate the charging operation. A typical sequence presently used (single gas off-take) is as follows:

1. The car hoppers are filled with a specific coal volume determined by the measuring sleeve on each hopper.

2. The car is moved to the oven to be charged and spotted manually using a visual spotting target. After the car is properly positioned, the operator pushes a CAR SPOTTED PB which satisfies a requirement that the car must be positioned to initiate any charging functions. The larryman operates a

MANUAL CHARGING SEQUENCE (continued)

2. (continued)
   pushbutton to clean the gooseneck of the oven to be pushed (two ovens south) with the gooseneck cleaner.*

3. At about the same time, the pusher machine operator removes the pusher side door of the oven to be pushed, and then positions the pusher for single spot pushing and leveling.

4. The leveler door is opened and the pusher operator advances the leveler bar until its smoke seal is positioned over the door opening. He then notifies the charging operator over the voice communication system that charging can begin.

5. The steam on PB is operated to place the oven on-the-main by turning on aspirating steam, opening the damper, and closing the standpipe cap of the oven to be charged.

6. The charging car drop sleeves are lowered into the open charging holes (one PB for each drop sleeve).

7. The butterfly valves are opened and oscillated by operating the individual push buttons.

8. The operator observes the top coal level indicators. The individual lights are energized when the coal level drops about two feet in the hopper measuring sleeve (about 10-15 seconds). Vibrators are normally used at all times during charging. When selected, they operate whenever the butterflies oscillate. If for any reason the coal flow does not start in a particular hopper, the operator uses a bar to get it started.

9. The operator stops the coal flow at #1 and #2 hoppers as the respective 75% coal charged lights turn ON. #3 hopper continues to empty.

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* This assumes successful use of the hydraulically operated gooseneck cleaner scheduled for installation March ,1974.

MANUAL CHARGING SEQUENCE (continued)

10. The larryman notifies the pusher operator to start leveling when the first 75% coal level light turns ON, provided the top level indicators show that coal flow has started from all hoppers. If for any reason coal flow has not started from a hopper, he initiates leveling after the 75% coal charge level is indicated on all three hoppers.

11. As soon as the pusherman notifies the larryman that leveling has started, the #1 and #2 butterfly valve pushbuttons are operated to resume oscillation and complete the coal charge. As the hoppers empty, bottom level detectors automatically close the respective butterfly valves.

12. After all three hoppers are empty, the larryman notifies the pusherman, who makes the final leveler passes before retracting the bar and closing the leveler door.

13. The pusherman tells the larryman when the leveler door is closed so that sequential re-lidding (1-2-3) of charging holes is completed. (Operates HOPPER RAISE PB, then REPLACE LID PB for each hopper).

14. The operator uses E-Travel PB to retract the lever arm without turning OFF the aspirating steam and moves the car two oven spaces south and spots the car. The aspirating steam is left on the charged oven to protect the larry car when part of it is spotted over the charged oven during this next operation.

15. The oven that is next to be pushed in this series is dampered OFF (DAMPER PB) and the lids of the oven just pushed are removed (REPLACE LID PBs) to decarbonize the charging holes.

16. The car returns to the coal bin, and the lidman turns off aspirating steam of the oven just charged.

SECTION V

CHARGING EQUIPMENT DESCRIPTION

GRAVITY FEED LARRY CAR

The prototype equipment built was designed to satisfy the requirements of this system at P-4 Battery (Figure 7). This battery consists of 79 ovens of Koppers - Becker underjet design with a single collecting main on the pusher side. The ovens are rated 693 ft^3 with hot dimensions of 13' - 2 1/2" high, 12'- 2 1/2" to the coal line, 43' - 11" long, and 16 5/8" average width with a 3 1/2" taper. Figure 8 shows a cross section through the battery.

The design of the gravity feed larry car is shown on Figure 9 and 10. Based on the results of hopper design research by U. S. Steel the main hopper was built with a 67^{o} bin angle and a 24 inch diameter opening. A drop sleeve underneath each hopper is lowered to seat within the charging hole ring. The drop sleeve is supported by gimbal rings which permit lateral movement so that proper seating is still achieved with a maximum misalignment of 1 1/2" with respect to the charging hole ring.

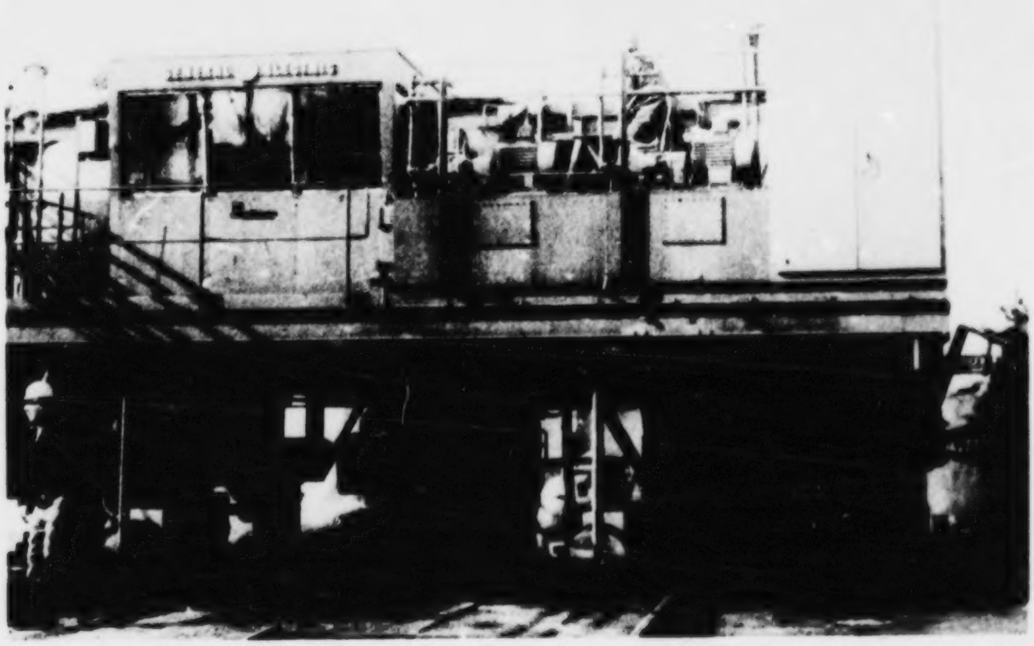
The bottom of the drop sleeve contains a butterfly valve which oscillates approximately 45^{o} in a cylindrical section to control the coal feed and feed rate. The rate of coal feed is a function of hydraulic pressure and the angle of oscillation. The dimensional design of the drop sleeve with respect to the hopper cylinder assures a coal seal at all times during charging. A rotating eccentric vibrator is mounted on the conical portion of each hopper to assist with the coal feed.

The butterfly valve and drop sleeve motions are hydraulically powered. In the event of a hydraulic failure, return springs were provided to raise the drop sleeve sufficiently to clear the charging holes. The operating positions of the drop sleeve feeder are shown in Figure 11.

Hopper Coal Level Control

Three coal level indicators were furnished for each hopper. A top level sensor indicates by a visual light that the hopper

AISI/EPA LARRY CAR



VIEW FROM SOUTH END OF LARRY CAR DURING A CHARGE, BUT PRIOR TO START OF LEVELING.

FIGURE 7

CROSS SECTION THROUGH BATTERY P-4

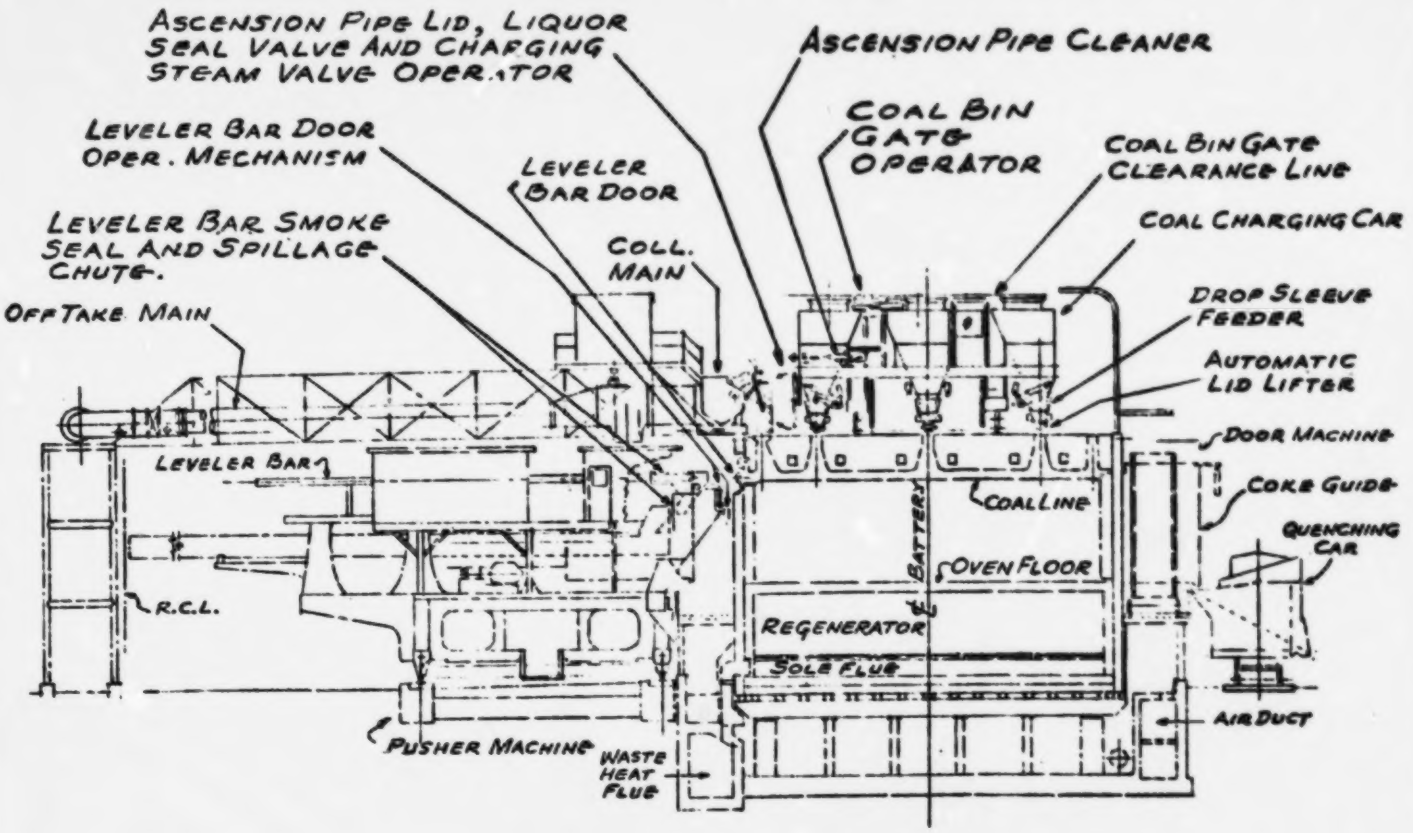
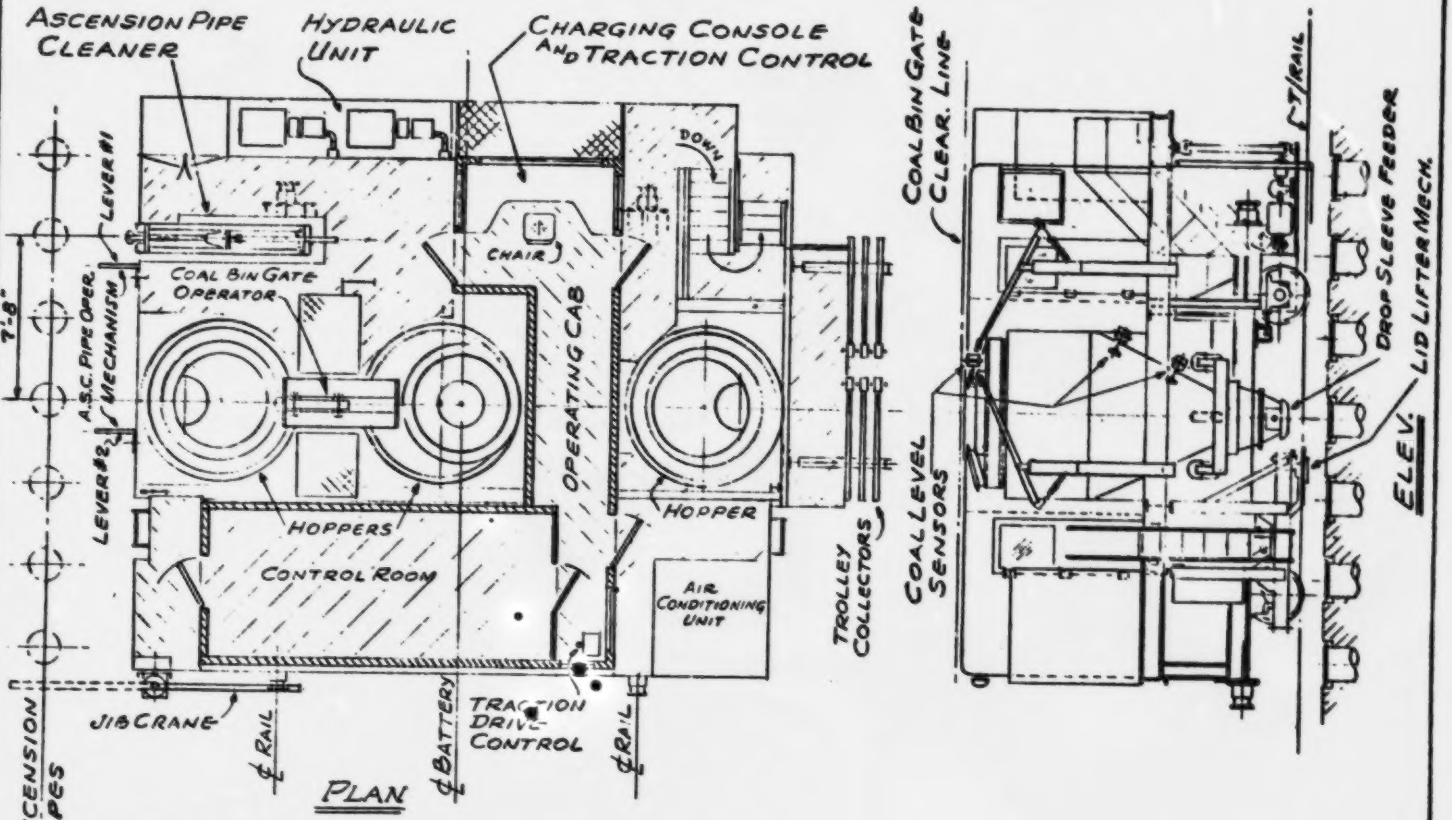

ASCENSION PIPE LID, LIQUOR SEAL VALVE AND CHARGING STEAM VALVE OPERATOR
ASCENSION PIPE CLEANER
COAL BIN GATE OPERATOR
LEVELER BAR DOOR OPER. MECHANISM
COAL BIN GATE CLEARANCE LINE
LEVELER BAR DOOR
COAL CHARGING CAR
LEVELER BAR SMOKE SEAL AND SPILLAGE CHUTE.
COLL. MAIN
OFF TAKE MAIN
DROP SLEEVE FEEDER
AUTOMATIC LID LIFTER
DOOR MACHINE
LEVELER BAR
COKE GUIDE
COAL LINE
BATTERY ℄
QUENCHING CAR
OVEN FLOOR
R.C.L.
REGENERATOR
SOLE FLUE
AIR DUCT
PUSHER MACHINE
WASTE HEAT FLUE

Figure 8

COAL CHARGING CAR ARRANGEMENT


ASCENSION PIPE CLEANER
HYDRAULIC UNIT
CHARGING CONSOLE AND TRACTION CONTROL
LEVER #1
COAL BIN GATE OPERATOR
A.S.C. PIPE OPER. MECHANISM
LEVER #2
7'-8"
CHAIR
DOWN
OPERATING CAB
HOPPERS
HOPPER
CONTROL ROOM
AIR CONDITIONING UNIT
TROLLEY COLLECTORS
JIB CRANE
℄ RAIL
℄ BATTERY
TRACTION DRIVE CONTROL
℄ RAIL
℄ ASCENSION PIPES
PLAN
COAL BIN GATE CLEAR. LINE
COAL LEVEL SENSORS
℄ T/RAIL
DROP SLEEVE FEEDER
LID LIFTER MECH.
ELEV.

LEVER #1 - DAMPER OFF OVEN
LEVER #2 - PLACE OVEN ON-THE-MAIN

Figure 9

COAL CHARGING CAR ARRANGEMENT

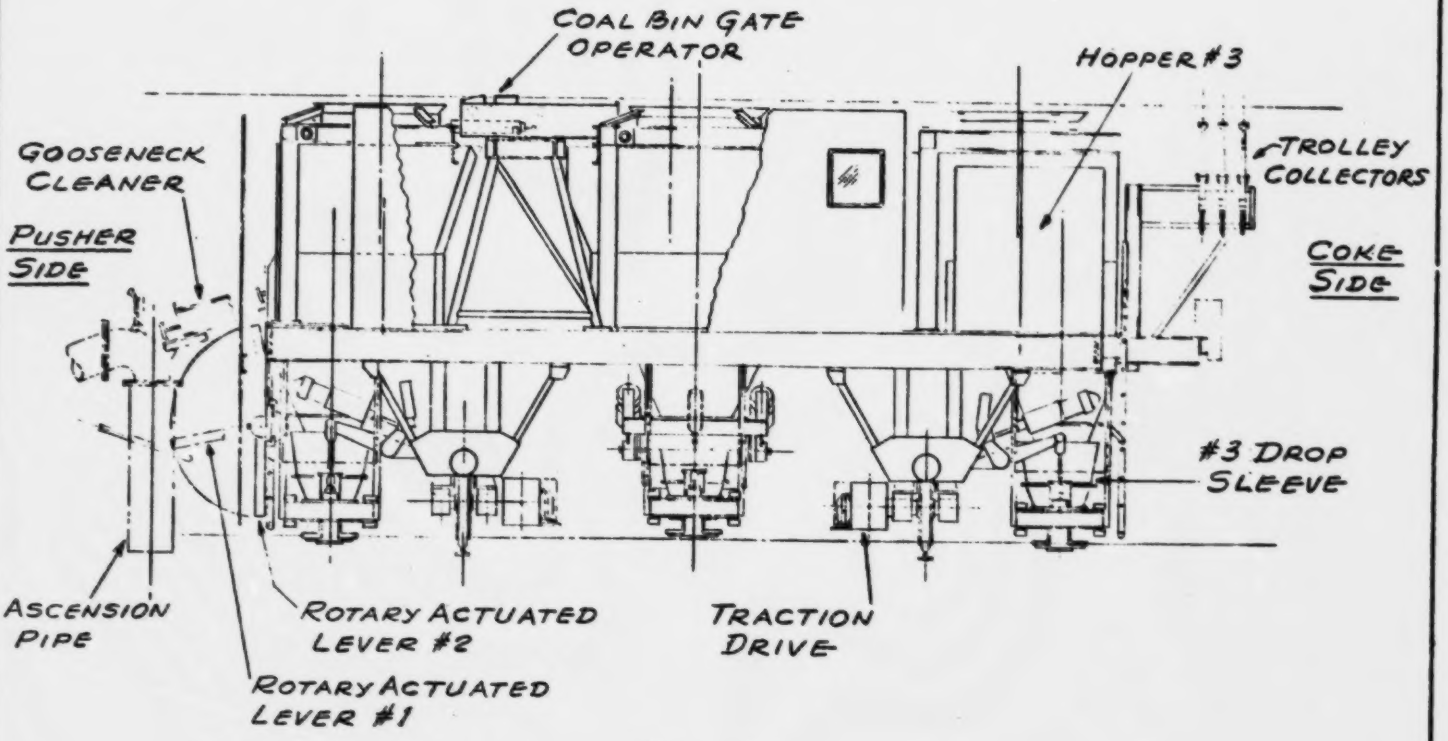

COAL BIN GATE OPERATOR
HOPPER #3
GOOSENECK CLEANER
TROLLEY COLLECTORS
PUSHER SIDE
COKE SIDE
#3 DROP SLEEVE
ASCENSION PIPE
ROTARY ACTUATED LEVER #2
TRACTION DRIVE
ROTARY ACTUATED LEVER #1

Figure 10

DROP SLEEVE FEEDER OPERATING POSITIONS

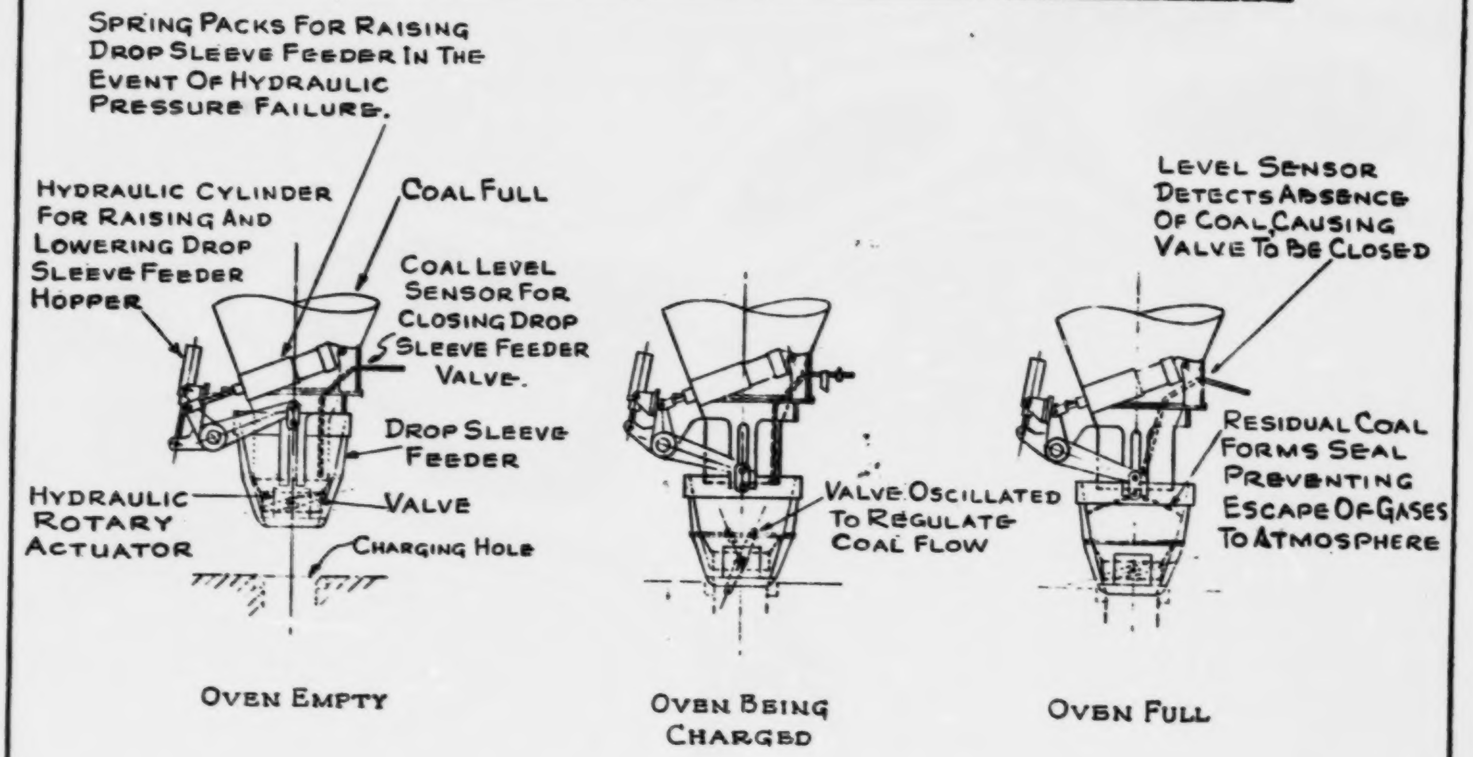

SPRING PACKS FOR RAISING DROP SLEEVE FEEDER IN THE EVENT OF HYDRAULIC PRESSURE FAILURE.
HYDRAULIC CYLINDER FOR RAISING AND LOWERING DROP SLEEVE FEEDER HOPPER
COAL FULL
COAL LEVEL SENSOR FOR CLOSING DROP SLEEVE FEEDER VALVE.
DROP SLEEVE FEEDER
HYDRAULIC ROTARY ACTUATOR
VALVE
CHARGING HOLE
OVEN EMPTY
VALVE OSCILLATED TO REGULATE COAL FLOW
OVEN BEING CHARGED
LEVEL SENSOR DETECTS ABSENCE OF COAL CAUSING VALVE TO BE CLOSED
RESIDUAL COAL FORMS SEAL PREVENTING ESCAPE OF GASES TO ATMOSPHERE
OVEN FULL

Figure 11

Hopper Coal Level Control (continued)

has been filled with coal. It also tells the operator that the coal has started to discharge from the hopper at the beginning of the charging cycle.

A second coal level sensor indicates when approximately 75% of the coal charge is in the oven. With manual sequencing the operator closes the butterfly valve and requests leveling to start. With automatic sequencing this sensor causes the butterfly valve to close, and after all three hoppers have reached this level, the larry car signals the pusher to start leveling.

A third coal level sensor indicates when the hopper has emptied and causes the butterfly valve to close with a 15" coal seal remaining. The closing of the butterfly is initiated directly from the sensor regardless of whether manual or automatic sequence was used.

The original level sensor selected was a paddle wheel motor driven device which rotates in the absence of coal. This unit is furnished by Monitor Mfg. by the name "Bin-O-Matic". The approximate hopper location for these devices is shown in Figure 9.

Automatic Lid Lifters

Automatic lid lifters are provided to REMOVE and REPLACE lids (Figure 12). Each lid lifter consists of a magnet which is moved vertically and horizontally by two hydraulic cylinders. When lids are removed, they are placed on the battery to permit decarbonization of charging holes. To effect a proper oven seal when replacing lids, they are oscillated 30° for about four cycles. A hydraulic driven rotary actuator pulls and pushes the oscillating links attached to the magnet. Bottom pins on the magnet engage radial grooves in the lid to provide for positive motion.

In case of a hydraulic failure, a pair of return springs will raise the lid lifter sufficiently to clear the charging hole.

Automatic Lid Lifters (continued)

The following sequence occurs when removing lids: lid lifter extends, lowers to charging hole, turns magnet ON, raises (picks up lid), retracts, lowers, turns magnet OFF (lid now on battery), raises to the travel position.

The following sequence is followed when replacing lids: lid lifter lowers, turns on magnet, raises (picks up lid from battery), extends, lowers (lid now placed in charging hole ring), oscillates the lid over an arc of about 30 ° to seal the lid, turns magnet OFF, raises and retracts to the travel position.

Individual REMOVE LID and REPLACE LID push buttons are provided for each lid lifter. Sensors monitor all movements which must occur in sequence or the cycle will stop, causing a buzzer to sound and an annunciator alerts the operator that the cycle is not complete. Indicating lights monitor the actuation of all sensors to help the operator identify the incomplete sequence. A special emergency manual switch which bypasses the sequence sensors is provided to permit any single motion of any or all lid lifters. This control arrangement has proved to be very effective and is well accepted by the operators.

Damper, Steam Valve, and Standpipe Cap Operating Linkages

Prior to charging, it is necessary to place the oven "on-the-

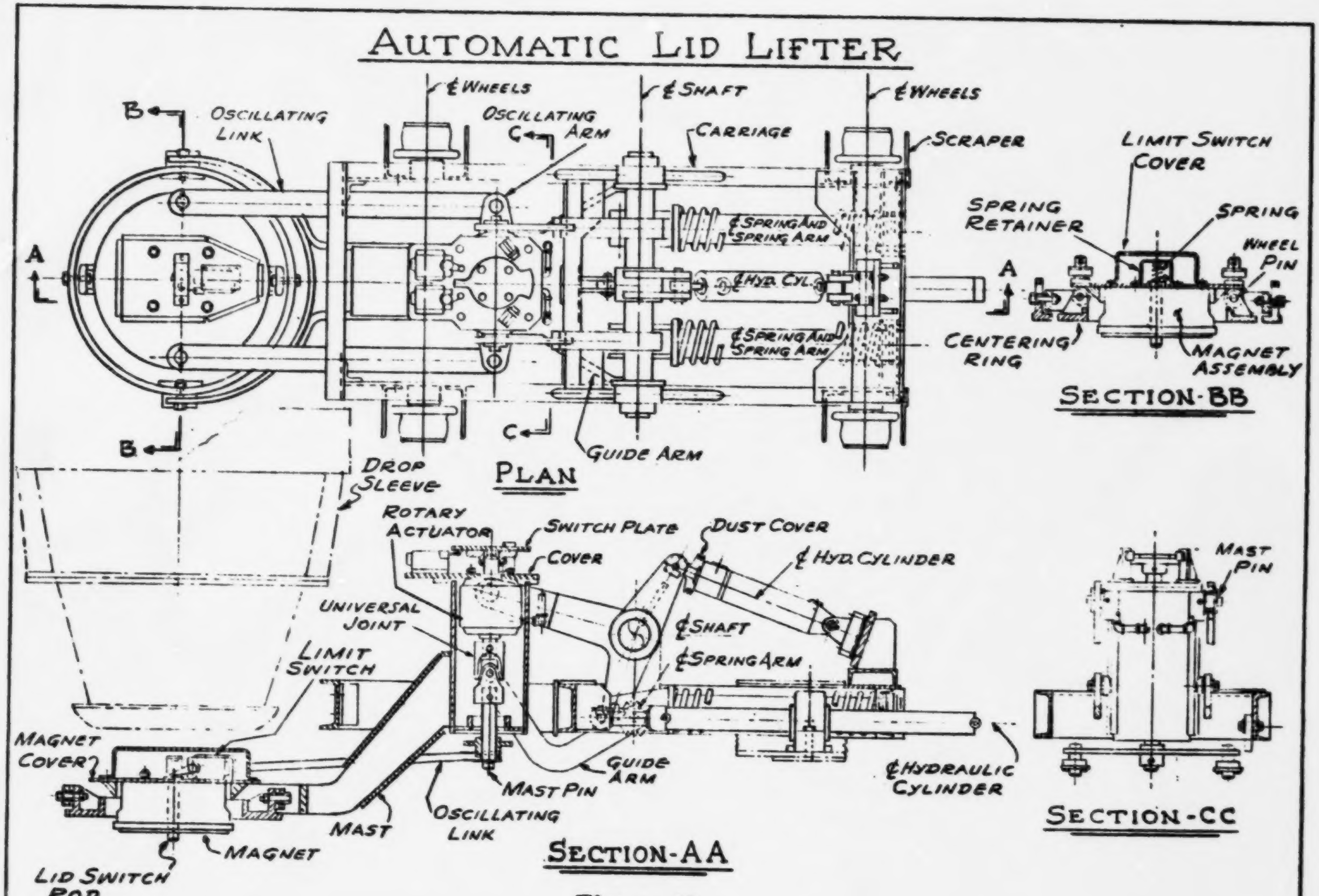

AUTOMATIC LID LIFTER
℄ WHEELS
℄ SHAFT
℄ WHEELS
B
OSCILLATING LINK
OSCILLATING ARM
C
CARRIAGE
SCRAPER
LIMIT SWITCH COVER
SPRING RETAINER
SPRING
WHEEL PIN
A
℄ SPRING AND SPRING ARM
℄ HYD. CYL.
℄ SPRING AND SPRING ARM
A
CENTERING RING
MAGNET ASSEMBLY
SECTION-BB
B
C
GUIDE ARM
DROP SLEEVE
PLAN
ROTARY ACTUATOR
SWITCH PLATE
COVER
DUST COVER
℄ HYD. CYLINDER
MAST PIN
UNIVERSAL JOINT
℄ SHAFT
℄ SPRING ARM
LIMIT SWITCH
MAGNET COVER
GUIDE ARM
MAST PIN
℄ HYDRAULIC CYLINDER
MAST
OSCILLATING LINK
MAGNET
LID SWITCH ROD
SECTION-AA
SECTION-CC

Figure 12

Damper, Steam Valve, and Standpipe Cap Operating Linkages (continued)

main". This consists of opening the steam valve, closing the standpipe cap, and opening the damper valve. After the oven is charged, the steam is turned off. Prior to pushing the coke, the oven is dampered off. This consists of closing the damper valve, allowing sufficient time for the valve to seal with flushing liquor, and then opening the standpipe cap.

There are three linkage systems mounted to each standpipe: (1) steam valve operating mechanism, (2) stand pipe cap operating mechanism, and (3) pullman damper valve operating mechanism. These three mechanisms are operated by two rotating lever arms mounted on the larry car. One arm, lever #2, raises to operate all three mechanisms to place the oven on-the-main (Figure 13). When lever #2 lowers, it operates only the steam valve linkage to turn off the steam after a charge. Lever #1 lowers to damper off an oven by operating the standpipe cap and damper valve mechanisms (Figure 14). The damper lever and standpipe cap lever mounted to the ascension pipe each travel about 40°.

In placing the oven on-the-main with the car operated lever #2, the first 24° travel of the damper lever in the up direction will open the damper valve. The standpipe cap will not start closing until its lever has travelled about 16°. The steam is also being turned ON during this operation so that sufficient steam is present to prevent any appearance of coke oven gas. After the oven is charged, the steam is turned off by lowering lever #2. The energized electro-magnet attached to the lever will pull the shoe plate down with it. The counterweight attached to the damper valve mechanism, being in the "over-center" UP position will hold the damper open. The standpipe cap will remain closed, since it requires a downward lever force to open. If desired by the operator the lever can be lowered without turning off the steam. An EMERGENCY TRAVEL sequence will lower the arm without energizing the magnet. The steam linkage remains in place.

When the oven is to be dampered-off, the car operated lever #1 rotates in a DOWN direction under a minimal hydraulic pressure. This will contact the damper lever and rotate it 16°. At this point the car operated lever #1 will contact the standpipe cap lever, which causes lever #1 to stall. The damper arm

OVEN ON THE MAIN

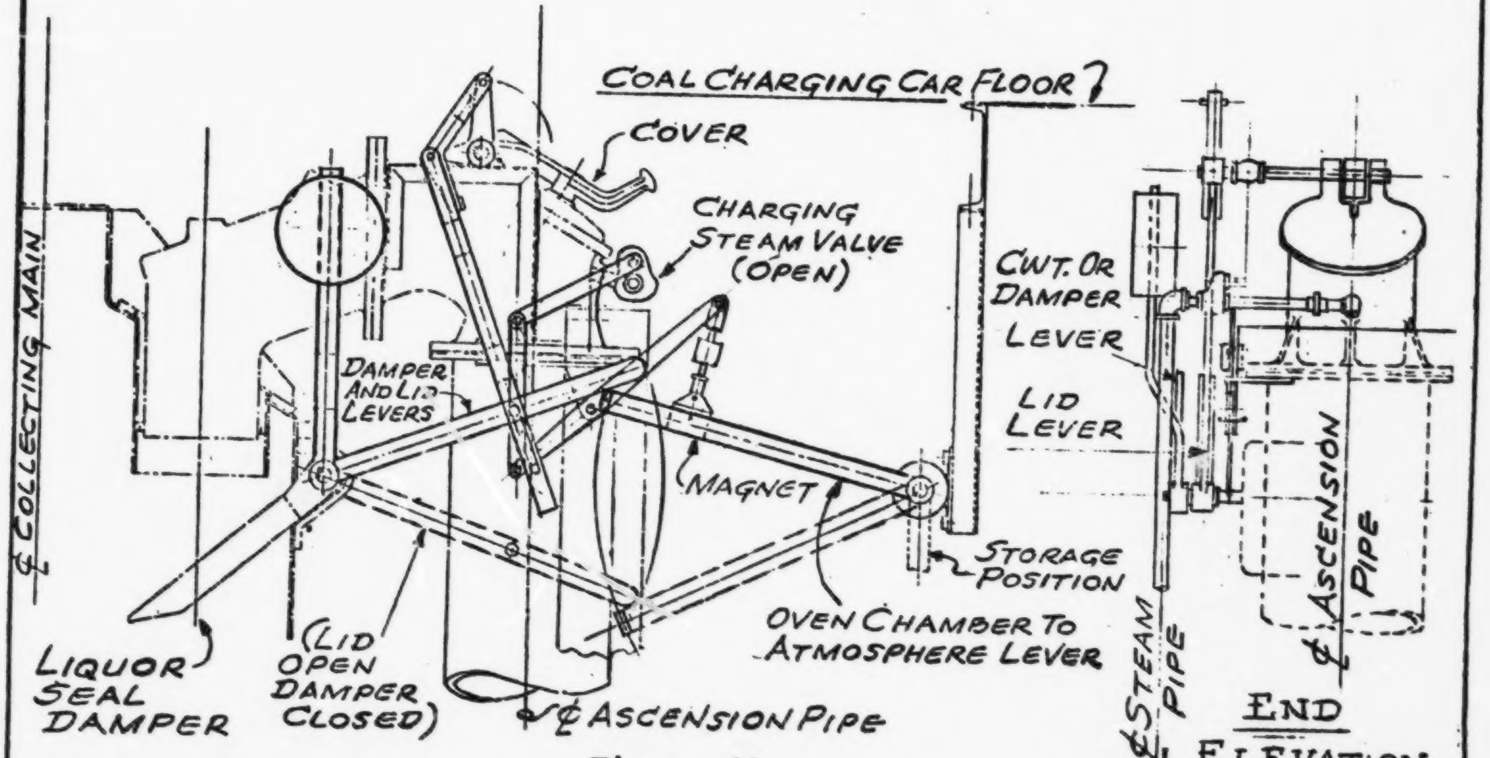

COAL CHARGING CAR FLOOR
COVER
CHARGING STEAM VALVE (OPEN)
CWT. OR DAMPER LEVER
LID LEVER
DAMPER AND LID LEVERS
MAGNET
STORAGE POSITION
OVEN CHAMBER TO ATMOSPHERE LEVER
℄ COLLECTING MAIN
LIQUOR SEAL DAMPER
(LID OPEN DAMPER CLOSED)
℄ ASCENSION PIPE
℄ STEAM PIPE
℄ ASCENSION PIPE
END ELEVATION

Figure 13

OVEN DAMPERED-OFF

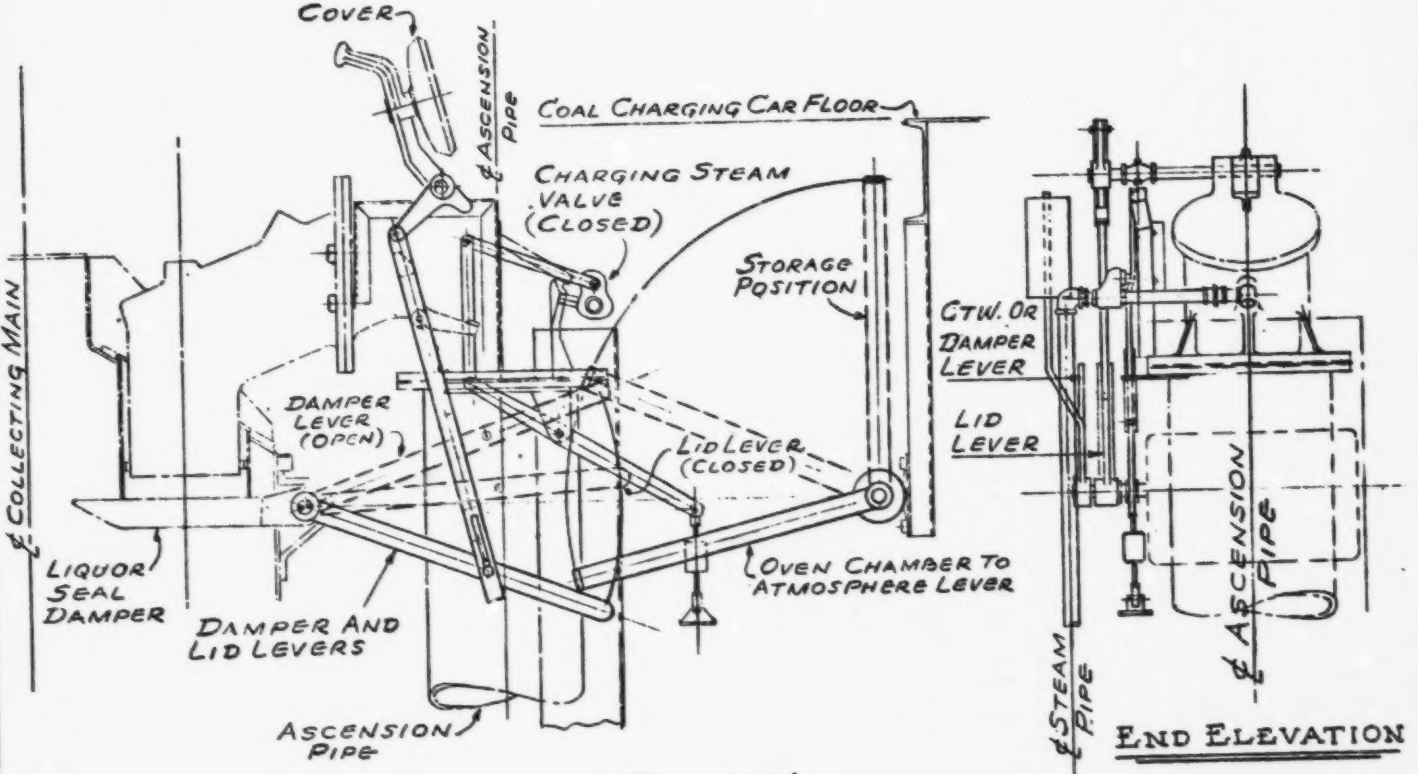

Cover
℄ Ascension Pipe
Coal Charging Car Floor
Charging Steam Valve (Closed)
Storage Position
℄ Collecting Main
Damper Lever (Open)
Lid Lever (Closed)
Liquor Seal Damper
Damper and Lid Levers
Oven Chamber to Atmosphere Lever
Ascension Pipe
Ctw. or Damper Lever
Lid Lever
℄ Steam Pipe
℄ Ascension Pipe
End Elevation

Figure 14

Damper, Steam Valve, and Standpipe Cap Operating Linkages (continued)

counterweight is now past the neutral point and should fall free the remaining 24° of travel thus closing the Pullman damper. After a preset time delay from actuation of lever #1, normal hydraulic pressure is applied which provides sufficient force to cause the standpipe cap lever to be moved through its final 24° travel, thus opening the standpipe cap. The purpose of the time delay is to permit the Pullman damper to fill sufficiently with flushing liquor to prevent the coke oven gas in the collecting main from being discharged through the standpipe cap opening.

Gooseneck Cleaner

A mechanized cleaner permitted an operator to control the cleaning of goosenecks by initiating the sequence from within the cab. The original device shown on Figure 15 consists of rotating flails mounted on a shaft direct driven by a motor. The cleaner mechanism is powered by two hydraulic cylinders. The positioning cylinder moves the cleaner from the travel position until the guide frame rests in the gooseneck inspection cap opening. The extend cylinder then causes the drive head to enter in a circular path to get past the opening after which it extends to its maximum stroke before retracting.

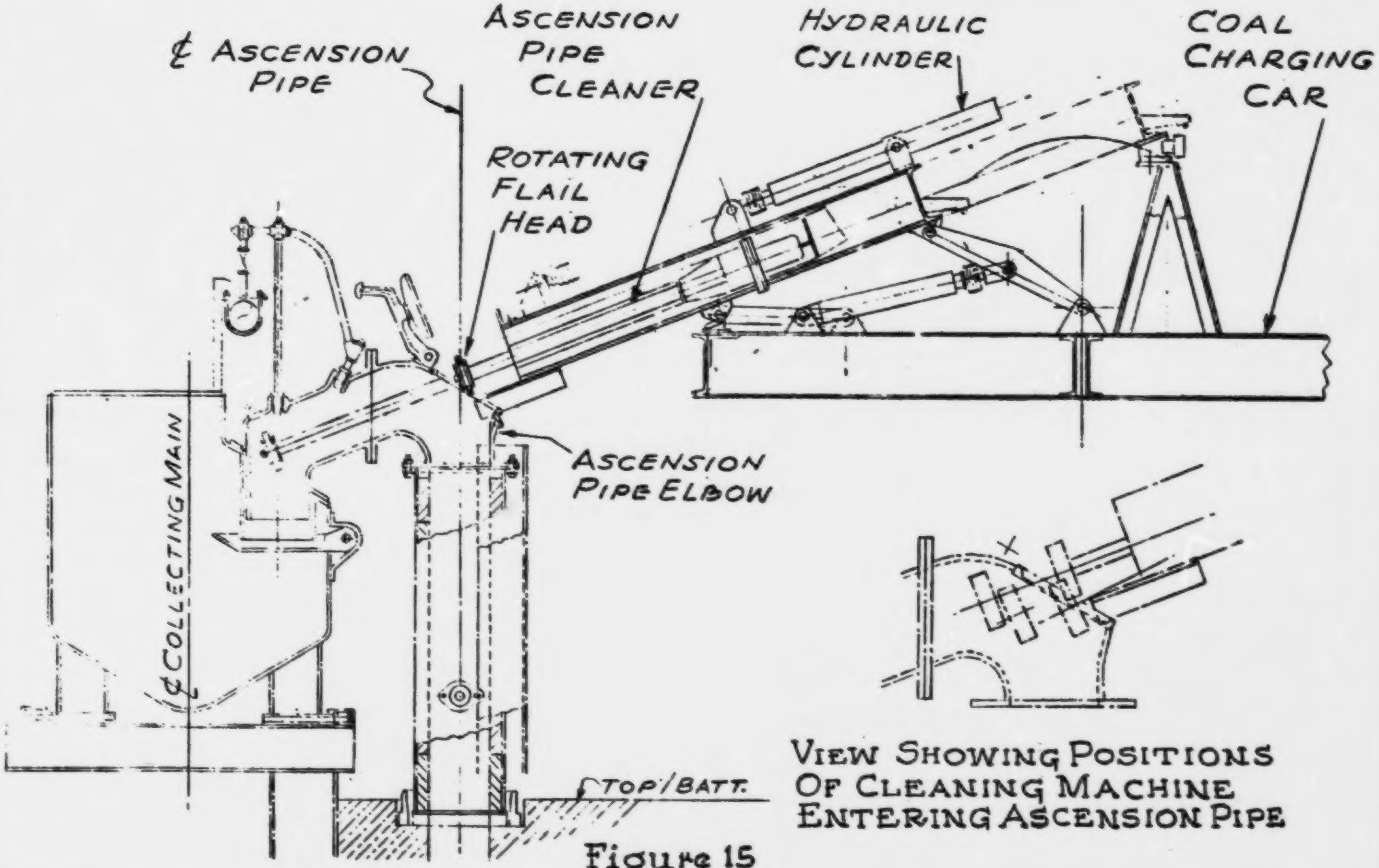
Coal Bin Gate Operator

A hydraulically driven coal bin gate operator permits the sequence of loading the larry car at the coal bin to be initiated from within the cab.

Traction Drive

The traction drive is controlled from a common thyristor power supply which supports two independently driven 10-horsepower mill-type motors. The mechanical arrangement can be seen in Figure 9. The drive system has low backlash to permit accurate car positioning. The speed regulated drive has a maximum speed of 400 FPM but can be controlled at 2% rated speed for accurate spotting over a charging hole.

ASCENSION PIPE CLEANER


℄ ASCENSION PIPE
ASCENSION PIPE CLEANER
HYDRAULIC CYLINDER
COAL CHARGING CAR
ROTATING FLAIL HEAD
ASCENSION PIPE ELBOW
℄ COLLECTING MAIN
TOP/BATT.

VIEW SHOWING POSITIONS OF CLEANING MACHINE ENTERING ASCENSION PIPE

Figure 15

Coal Charging Car Positioning System

This charging system requires accurate spotting of the coal charging car over the oven in order to effect a tight seal between the hoppers and charging holes. Accurate positioning is also required for use of the ascension pipe cleaner, the damper actuating levers, and lid lifters.

An automatic spotting system was provided so that the car would be automatically positioned. The system is designed to position the car within a band of 0.35". Because the sensing position vane switches operate with a repetitive accuracy of of ± 0.1", the stopping band (position and indication) is 0.75". The car is manually brought to within 46" north of the oven to be charged. A pushbutton operation then initiates the positioning within ± 0.35". Position is sensed by vane limit switches which move over brass vanes. Actuation of these limits cause the car to position as shown in Figure 16. These special static switches were furnished by G.E. in a water tight enclosure.

The larry car movable carriage (Figure 17) held the limits at a fixed position with respect to the stationary vanes on the battery by means of a wheel which rode on an angle above the vanes. The arm which attached the carriage to the larry car permitted variations between the position of the car (vertical and horizontal) and the brass vanes, but maintained a fixed position in the direction of larry car travel.

Hydraulic System

The hydraulic system provides the power to operate the lid lifters, hopper drop sleeves, butterfly valves, damper, steam and standpipe cap mechanisms, gooseneck cleaner, and the coal bin gate operator. There are two pressure compensated fixed displacement piston type pumps rated 27 GPM at 1000 psi and 1200 RPM. Only one pump is run at a time, and the other one is on stand-by service. Each pump is driven by a 25 HP motor. If the system pressure drops to approximately 300 psi, the preferred pump will shut down and the stand-by will start running. Part of this system can be seen in Figure 7 (page 31).

OPERATION OF LARRY CAR POSITIONING SYSTEM

OPERATING THE CAR SPOT P.B. CAUSES THE CAR TO TRAVERSE AT 10% SPEED. WHEN THE VANE LIMIT PX2C IS SENSED, THE CAR SPEED IS REDUCED TO 2%. WHEN VANE LIMIT PX2D IS SENSED, A STOP TRAVEL IS INITIATED. THE CAR WILL STOP BETWEEN PX2A AND PX2B. A CAR SPOT SIGNAL LIGHT IS ENERGIZED WHEN PX2A AND $\overline{\text{PX2B}}$ ARE SENSED. SINCE THE LIMITS OPERATE REPEATABLY WITHIN ± 0.1", THE SENSING BAND IS 0.75".

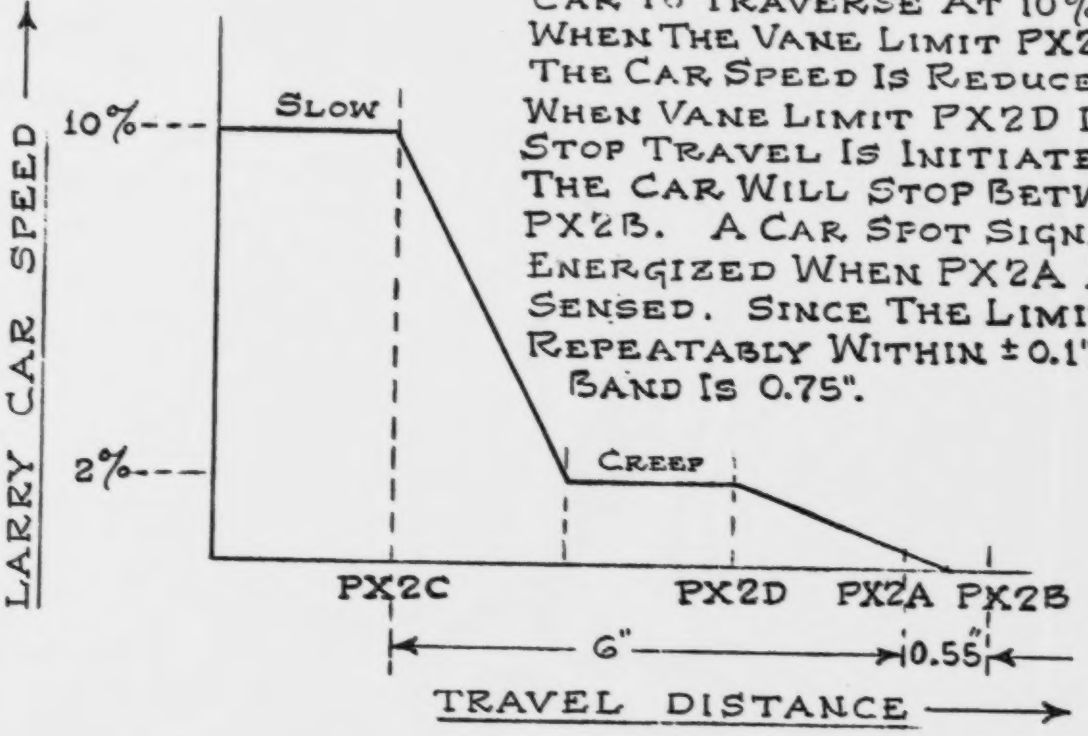
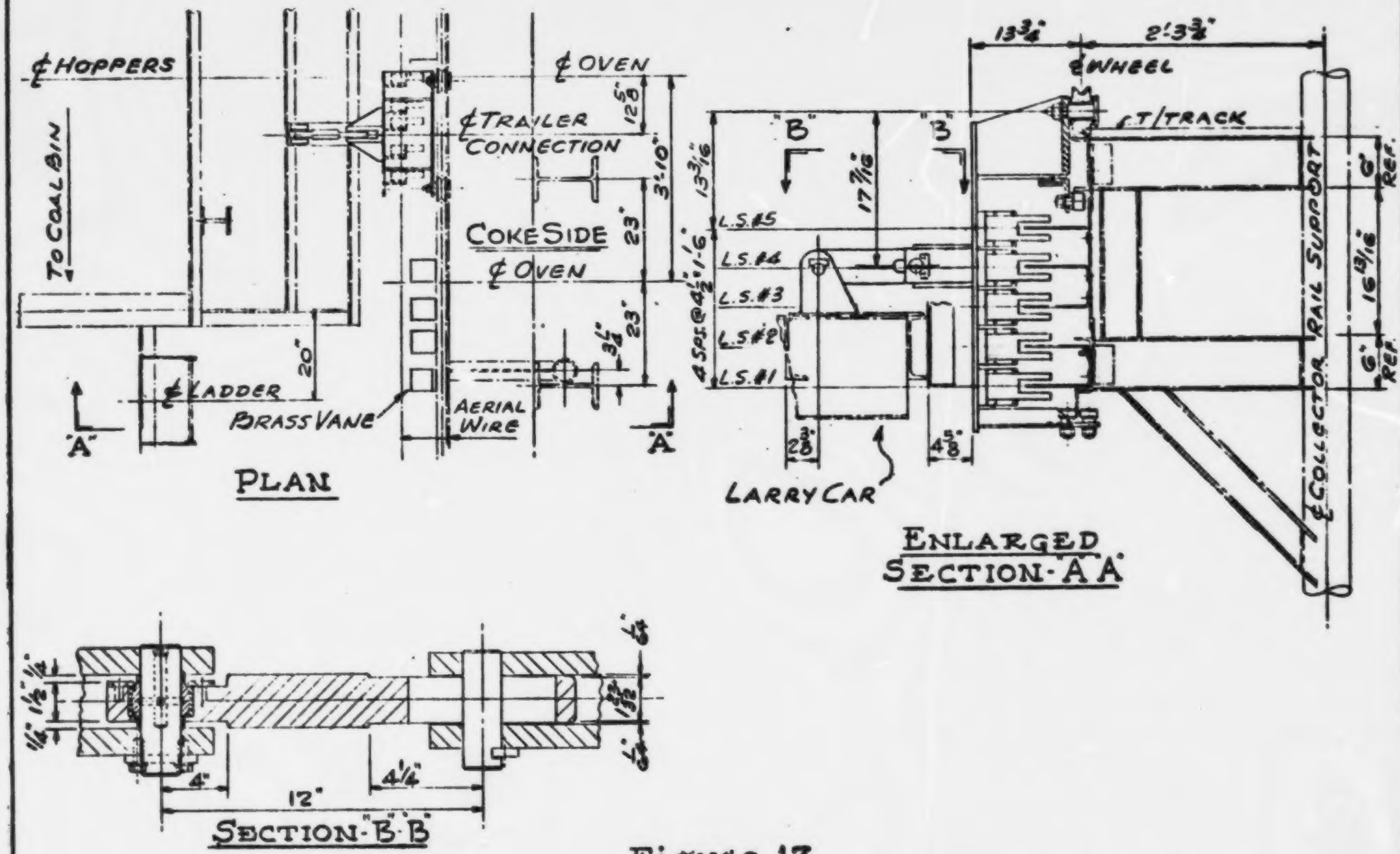


Figure 16

POSITIONING SYSTEM ARRANGEMENT



℄ HOPPERS
TO COAL BIN
℄ OVEN
℄ TRAILER CONNECTION
COKE SIDE
℄ OVEN
12 5/8"
3'-10"
23"
23"
3 1/4"
20"
℄ LADDER
BRASS VANE
AERIAL WIRE
"A"
"A"
PLAN
13 3/4"
2'-3 3/8"
℄ WHEEL
T/TRACK
"B"
"B"
17 7/16
13 3/16
4 SPS @ 4 1/2" = 1'-6"
L.S.#5
L.S.#4
L.S.#3
L.S.#2
L.S.#1
2 3/8"
4 5/8"
LARRY CAR
6" REF.
16 13/16
6" REF.
℄ COLLECTOR RAIL SUPPORT
ENLARGED SECTION "A"-"A"
1/4"
1 1/2"
1/4"
4"
12"
4 1/4"
SECTION "B"-"B"

Figure 17

Hydraulic System (continued)

The solenoid operated hydraulic valves, flow control valves, sequencing valves, and pressure switches are located in enclosed hydraulic panels. There are three identical panels (Figure 18) mounted at the end of the lid lifter frames at the north end of the car on the battery level that each contain all hydraulic valves for one lid lifter, drop sleeve, and butterfly valve. A fourth panel is mounted next to the pump units and contains the hydraulic valves for the pump units, coal bin gate operator, rotary actuators for the ascension pipe linkages, and the gooseneck cleaner.

Environmental Control Unit

A Buffalo Forge Company 5-ton packaged air conditioning and environmental control unit was furnished to improve the environmental conditions to which the larry car operator is exposed inside the operator's cab, as well as providing a suitable environment for the electrical controls housed inside the electrical control room.

The specifications for this unit limited the time weighted average concentrations (based on 8 hr. work day) inside the larry car to the following:

Coal Tar Pitch Volatiles	0.2 mg/M^3
SO_2	5 PPM
H_2S	10 PPM
CO	50 PPM

The final filter was to be designed for 99.9% removal of particles down to 1 micron in size.

This was to be a once-through system, using all outside air, to slightly pressurize the cab and heat and cool the air to maintain a temperature of 70°F ± 5°F in the operator's cab, and below 90°F in the electrical control room. The filtered air from the cab was to pass through a grill into the electrical control room and discharge out through a weighted louvre.

This one unit was to handle the ventilation of both the electrical control room (651 ft.^{3}) and the operator's cab (893 ft.^{3}), resulting in an approximate overall air change of one per

LID LIFTER AND DROP SLEEVE HYDRAULIC PANEL

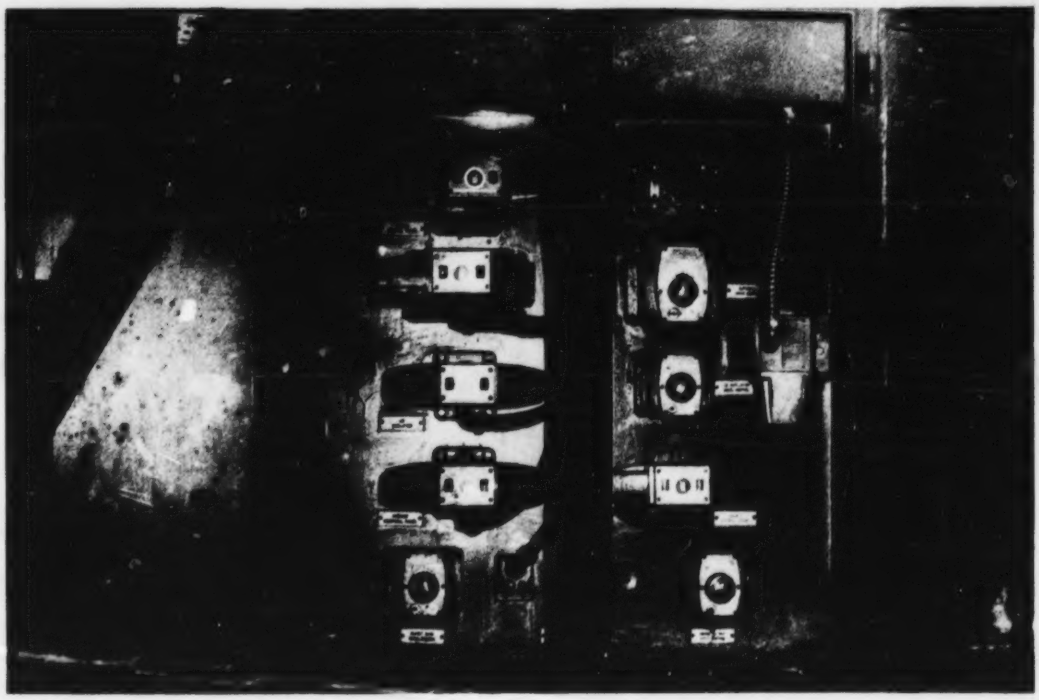


FIGURE 18

minute.

The inlet air is drawn through a bird screen and fixed louver downward to an AAF Co. Dual Pocket Dust Louvre Air Cleaner (65-4 design 2) with an auxilliary exhaust system removing about 20% of the "primary air" containing the large particles removed by this inertial type separator. The efficiency of the Dust Louvre is rated as 92% on Dry Arizona Coarse Road Dust, and 78% on Dry Fine Arizona Road Dust.

The air then discharges into a vertically mounted replaceable bag type cotton filter (AAF #2100 Dri-Pak, Class II) which has 95 sq. ft. of cloth area (24" x 24" x 36") and a rated overall efficiency of 95% (Atmosphere Dust Spot Test), and on the order of 90% efficiency at 1 micron particle size.

The filtered air then passes through a horizontally mounted charcoal filter bed (AAF-1000 24" x 24" x 8-3/4") which contains 45 pounds of activated charcoal for removal by absorption of gaseous contaminants. (SO_2, H_2S).

The air then passes through a cooling coil (6-row, copper fin, copper tube, direct expansion), thence through a 30 KW electric heating coil. The cooling coil receives its refrigerant from a 5 ton Lintern Model #960 heavy duty industrial compressor-condenser unit located adjacent to the ventilation unit on the larry car.

Finally, the air passes through a backward curved, limit load type fan, with a 1 1/2 hp motor, through the ductwork into the operator's cab and electrical control room.

Discharged air temperature is regulated by a combination of a course two-stage temperature sensor located in the inlet section and a final temperature sensor located downstream from the fan, inside the ductwork.

The arrangement of the unit can be seen in Figure 19. A view from the top of the larry car (figure 20) shows the air inlet the compresser cooling coils, and the air duct into the cab.

ENVIRONMENTAL UNIT ARRANGEMENT

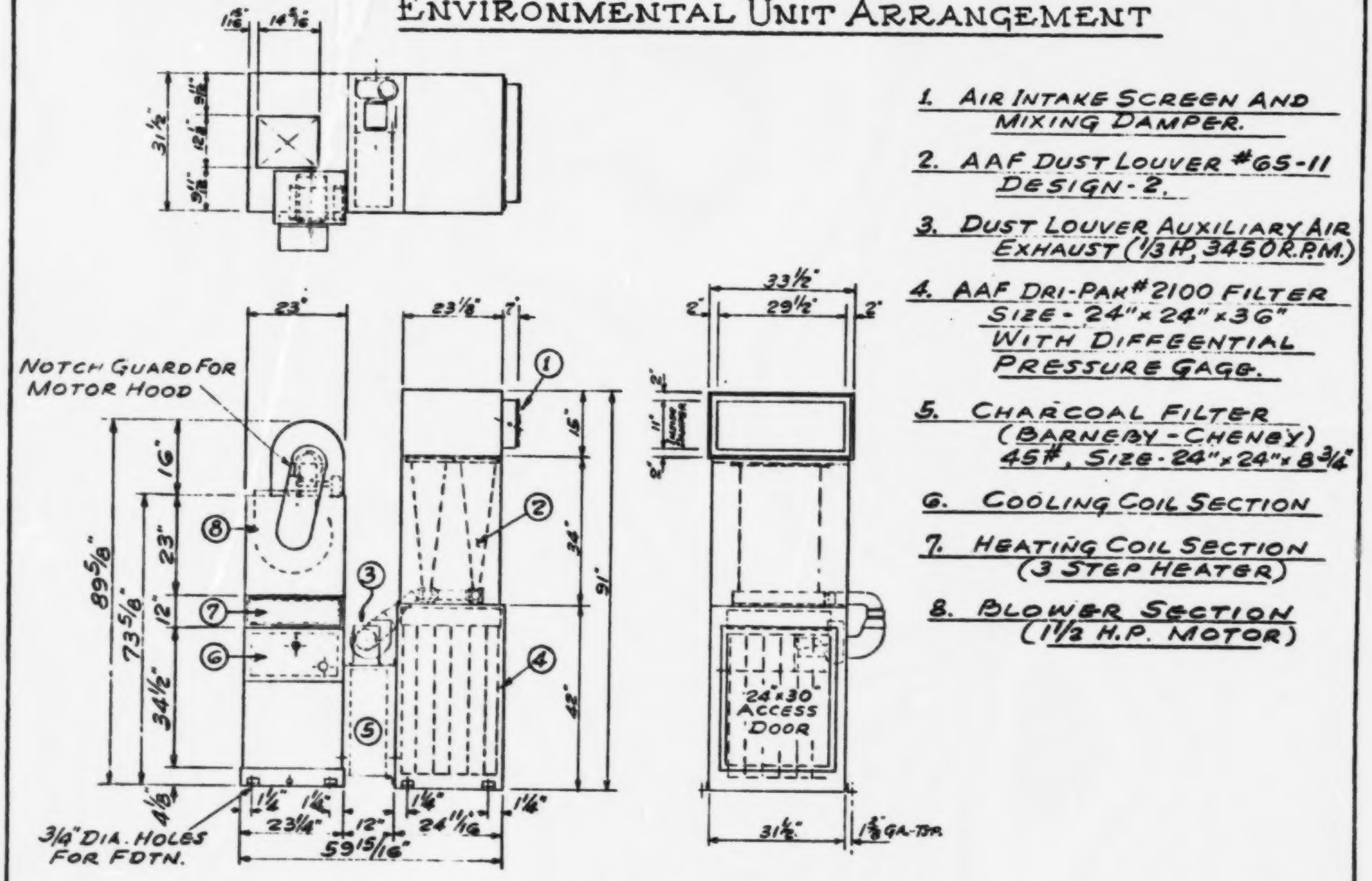

1. AIR INTAKE SCREEN AND MIXING DAMPER.
2. AAF DUST LOUVER #GS-11 DESIGN-2.
3. DUST LOUVER AUXILIARY AIR EXHAUST (1/3 HP, 3450 R.P.M.)
4. AAF DRI-PAK #2100 FILTER SIZE - 24" x 24" x 36" WITH DIFFEENTIAL PRESSURE GAGE.
5. CHARCOAL FILTER (BARNEBY-CHENEY) 45#, SIZE - 24" x 24" x 8 3/4"
6. COOLING COIL SECTION
7. HEATING COIL SECTION (3 STEP HEATER)
8. BLOWER SECTION (1 1/2 H.P. MOTOR)
NOTCH GUARD FOR MOTOR HOOD
3/4" DIA. HOLES FOR FDTN.
24"x30" ACCESS DOOR
1 1/16"
14 5/16"
31 1/2"
9 1/16"
12 1/2"
23"
23 1/8"
7"
16"
23"
12"
34 1/2"
89 5/8"
73 5/8"
4 1/8"
1 1/4"
23 1/4"
12"
24 11/16"
59 15/16"
15"
34"
42"
91"
33 1/2"
29 1/2"
2"
11"
31 1/2"
1 1/8" GA-TSR

Figure 19

ENVIRONMENTAL UNIT - TOP VIEW

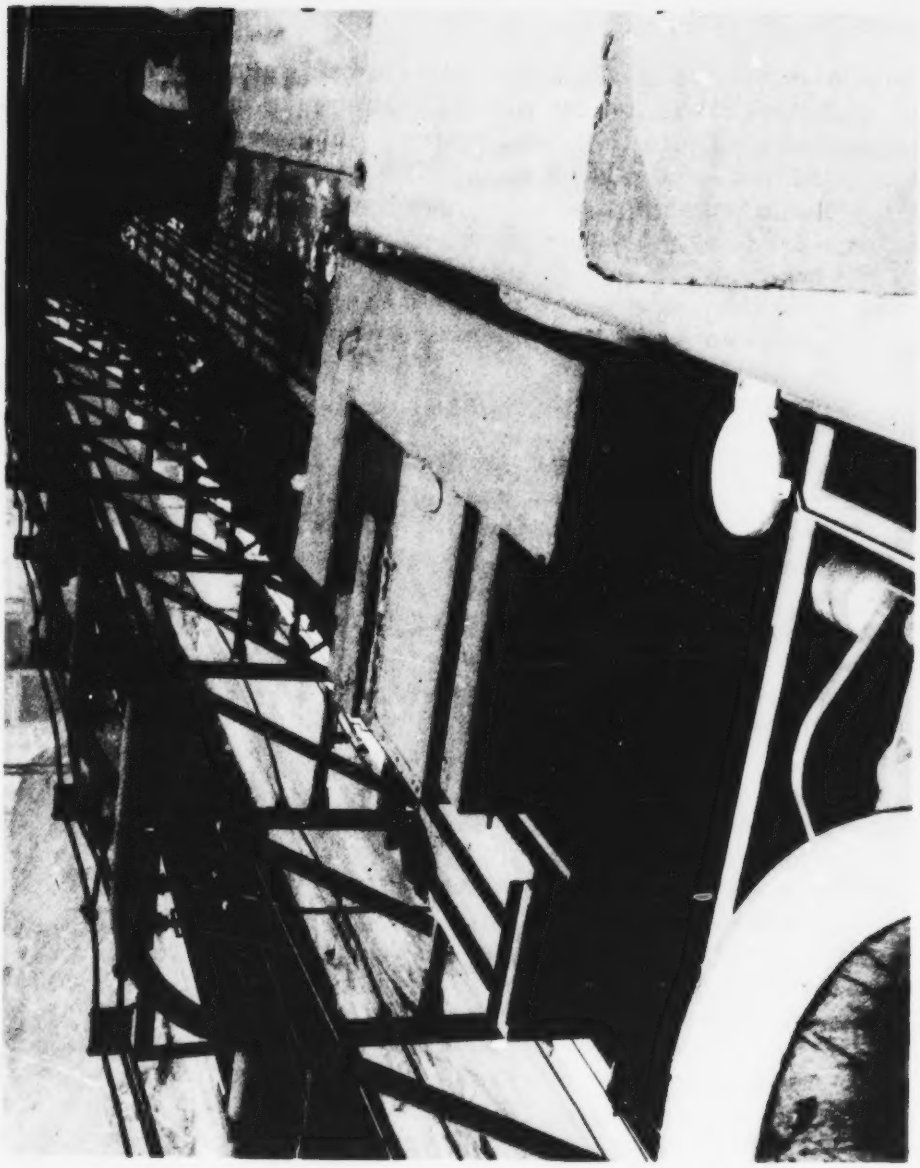


FIGURE 20

Electrical System

The electrical system for the larry car furnishes the necessary power and distribution to provide adequate and reliable means of operating the electrical equipment. The power system (460 volt, 3 phase, 60 Hz) was sized to handle two larry cars, with a maximum load on one. The design criteria were a load of 400 amperes and a maximum in plant line drop of 5% rated voltage.

The existing power system on this battery is 250 V.D.C. Since only D-C powered cars had been used on P-4, it was necessary to provide an additional set of collector rails. This arrangement can be seen on Figure 20 .

Since the quench tower is located at the south end of P-4 battery, 180 feet of power rail at the south end were stainless steel "T"-bar. The remaining "T"-bar was plain carbon steel.

The 460 volt supply at the larry car is divided into two separate sections of a motor control center. The first section consists of equipment that may be energized at all times whether or not the car is being operated. This supply, coming directly from the hot-rails, feeds a separate incoming line breaker. Loads from this source include:

1. Mercury lights
2. Environmental Control Unit
    a) Three separate heaters
    b) Air conditioning fan and secondary air blower
    c) Air compressor
3. Hydraulic System heater
4. Magnet feeder
5. 115-volt distribution panel

The second section consists of equipment that moves and requires an easy method of lock-out. The hot-rail feed for this portion goes first to a manual - magnetic disconnect located outside the operator's cab. This can be controlled from pushbuttons on the console, or manually opened. The supply from this device then feeds both the traction drive power conversion equipment and a separate incoming line breaker. Loads from this second breaker include:

1. Hydraulic pumps (2)

Electrical System (continued)

2. Vibrators (3)
3. Solenoid transformer and supply
4. Hydraulic Pump control

This method of load distribution has worked out very well. The major types of electrical equipment in the control room are:

1. Motor control center
2. Traction drive power converter and control
3. Sequencing logic cabinets (one for automatic, one for manual)
4. Output relay cabinet
5. Magnet controller cabinet
6. P.C.M. control cabinet

Larry Car - Pusher Machine Alignment

An interlock system (Figure 21) was provided to assure that the pusher machine and the larry car were aligned on the same oven prior to initiating a charging cycle. The interlock consisted of an ultra high frequency transmitter (10.2 GHZ) on the pusher machine and a similar type receiver on the larry car.

Coal Charging Car Operating Modes

Two operating modes were provided for use with this system: AUTOMATIC and MANUAL. In general the MANUAL mode sequenced the motions necessary to perform an operation such as REMOVE LIDS or OPEN AND OSCILLATE BUTTERFLY VALVES. The AUTOMATIC mode of operation sequenced the individual operations. In PREPARE-TO-FEED it would SPOT the car over the oven to be charged, REMOVE LIDS, if necessary, then lower the DROP SLEEVES. Simultaneously after the car was spotted, it would raise lever #2 to place the oven ON-THE-MAIN.

The control pushbuttons (PB) furnished for use by the operator were as follows:

Manual System -

1. Remove lid PB, replace lid PB (three sets - one for each lid)
2. Steam and damper on PB, steam off PB, damper off PB
3. Hopper drop sleeve up PB, down PB (three sets - one for each

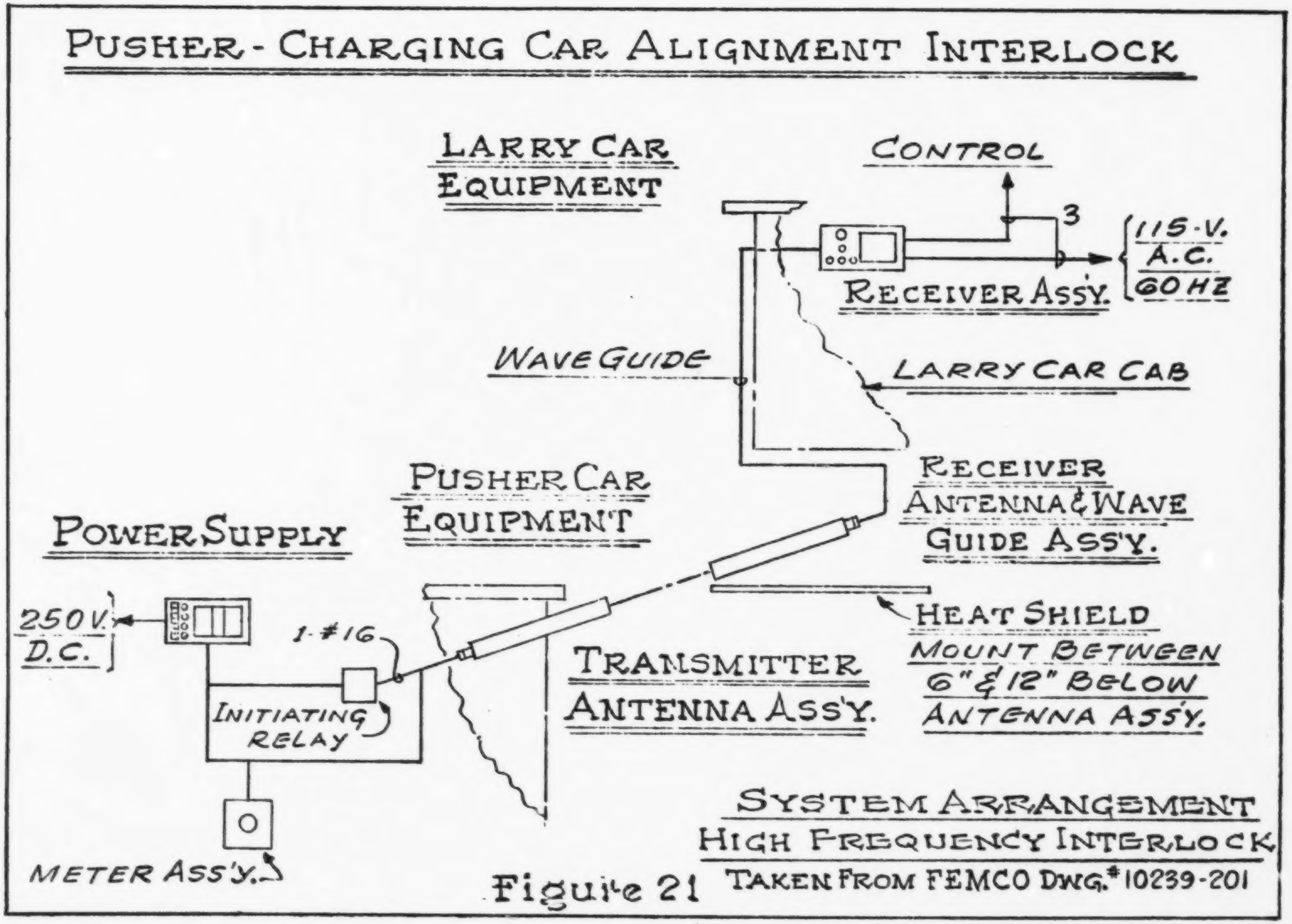

PUSHER - CHARGING CAR ALIGNMENT INTERLOCK
LARRY CAR EQUIPMENT
CONTROL
3
115-V. A.C. 60 HZ
RECEIVER ASS'Y.
WAVE GUIDE
LARRY CAR CAB
RECEIVER ANTENNA & WAVE GUIDE ASS'Y.
PUSHER CAR EQUIPMENT
POWER SUPPLY
250V. D.C.
1-#16
HEAT SHIELD
MOUNT BETWEEN 6" & 12" BELOW ANTENNA ASS'Y.
TRANSMITTER ANTENNA ASS'Y.
INITIATING RELAY
METER ASS'Y.
SYSTEM ARRANGEMENT
HIGH FREQUENCY INTERLOCK
TAKEN FROM FEMCO DWG.# 10239-201

Figure 21

Coal Charging Car Operating Modes (continued)

Manual System-(continued)

3. (continued)
   drop sleeve)
4. Butterfly valve oscillate PB, close PB (three sets - one for each butterfly)
5. Clean gooseneck PB.

Automatic System -

1. Auto Prepare-to-feed PB
2. Auto Feed PB
3. Auto Charge PB
4. Auto Remove lids PB

Carrier Current Signal System

The purpose of this system is to transmit and receive control requests and interlock signals between the coal charging car and the pusher machine as required by the automatic system. Refer to the system drawing shown in Figure 22.

The following signals are transmitted from the larry car to the pusher:

1. Status - Pusher is aligned
2. Request - Initiate alignment check
3. Alarm - Pusher not aligned
4. Request - Start leveling
5. Request - Make final level pass
6. Request - Retract leveler bar
7. Alarm - Not leveling
8. Alarm - Communication failure

The following signals are transmitted from the pusher to the larry car:

1. Status - Alignment being checked
2. Status - Leveler Bar operating
3. Status - Leveler bar smoke shield extended
4. Status - Chuck door closed and latched

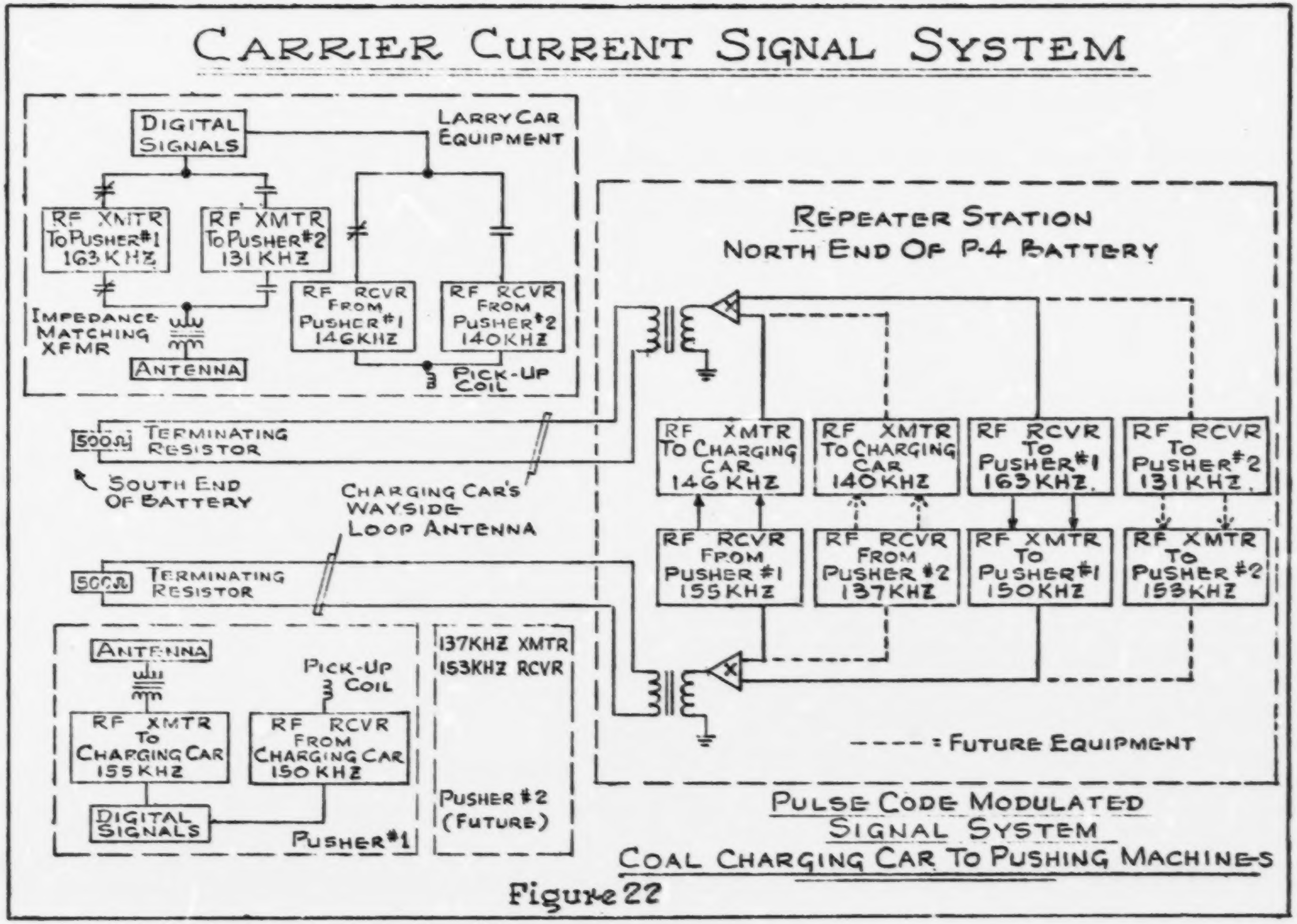

CARRIER CURRENT SIGNAL SYSTEM
LARRY CAR EQUIPMENT
DIGITAL SIGNALS
RF XMTR To PUSHER #1 163 KHZ
RF XMTR To PUSHER #2 131 KHZ
RF RCVR FROM PUSHER #1 146 KHZ
RF RCVR FROM PUSHER #2 140 KHZ
IMPEDANCE MATCHING XFMR
ANTENNA
PICK-UP COIL
500Ω TERMINATING RESISTOR
SOUTH END OF BATTERY
CHARGING CAR'S WAYSIDE LOOP ANTENNA
500Ω TERMINATING RESISTOR
REPEATER STATION
NORTH END OF P-4 BATTERY
RF XMTR TO CHARGING CAR 146 KHZ
RF XMTR TO CHARGING CAR 140 KHZ
RF RCVR TO PUSHER #1 163 KHZ.
RF RCVR TO PUSHER #2 131 KHZ.
RF RCVR FROM PUSHER #1 155 KHZ
RF RCVR FROM PUSHER #2 137 KHZ
RF XMTR TO PUSHER #1 150 KHZ
RF XMTR TO PUSHER #2 153 KHZ
ANTENNA
PICK-UP COIL
RF XMTR TO CHARGING CAR 155 KHZ
RF RCVR FROM CHARGING CAR 150 KHZ
DIGITAL SIGNALS
PUSHER #1
137 KHZ XMTR
153 KHZ RCVR
PUSHER #2 (FUTURE)
---- = FUTURE EQUIPMENT
PULSE CODE MODULATED SIGNAL SYSTEM
COAL CHARGING CAR TO PUSHING MACHINES

Figure 22

Carrier Current Signal System (continued)

The transmission of information is a five digit binary code sent serially. Error detecting is accomplished by alternate transmissions of code and complement. The receiver is not updated unless the complement of the second message matches that of the first transmission. If the receiver is not updated with a message within a certain pre-set time, a communication failure alarm occurs.

The system is designed on a priority basis. The signal of highest priority that becomes true is the one that is transmitted. Signals of lesser priority are not examined. It is possible to select a signal (for example - an alarm) that has the highest priority to be examined periodically only (one second out of ten) so that during the other times the remaining signals are examined on a priority basis. This requires careful selection of the priorities but has not limited the system.

For example after an alignment check was completed the "leveler bar operating" signal is examined first. If it is TRUE the other two signals are not seen. However it is known that if the "leveler bar is operating" the smoke seal must be in place and the chuck door is open. When the "leveler bar operating" signal is FALSE the "smokeshield in place" signal is checked. If this signal is TRUE, it is known that the chuck door must be open, since it had to be open in order to put the smokeshield in place. If the smoke shield is retracted, then the "chuck door closed" signal is examined. If no signal is TRUE, then a rest code (code "O") is transmitted so that a continual check is made to determine that the system is in good working order.

The transmitter coding is such that a "zero" logic signal will send low-shift and a "one" logic signal will send high-shift. The high and low shift frequencies will be + or - 100 H_z from the center frequency of the associated transmitter. The receiver discriminator then reads these signals respectively as + or - 1 volt d-c.

The system was designed so that the larry car could transmit signals to either of two pusher machines. A switch in the larry car selects the pusher to be used.

Carrier Current Signal System (continued)

Each machine has its own transmitter and receiver. The signal information is carried by a way-side loop consisting of a pair of parallel wires running the length of the battery for the charging car and for the pusher machine. The signal is inductively coupled to the respective transmitter and receiver by this loop.

Voice Communication System

Two voice communication systems were installed in the new larry car. One system provides direct voice communication with P-3 pusher, P-4 pusher, and the charging car. This system is used to coordinate the charging operation between the pusherman and the larryman. The second system permits the larryman to talk over the existing battery communication system which includes the foreman's office.

The voice system performs those functions for manual operation that the carrier current signal system does for automatic operation.

PUSHER MACHINE

Leveler Bar

The original concept of the charging system required that the leveler bar be self supporting so that it could be used as required shortly after the start of charging. Koppers determined that the existing leveler bar used at P-4 battery would not be self-supporting, when fully extended at elevated temperatures exceeding 500° F.

A new self-supporting leveler bar was furnished which featured the use of bulb angles for high strength and side cut-outs to minimize the over-all weight.

Leveler Bar Smoke Shield

A smoke shield was required around the leveler bar to seal

Leveler Bar Smoke Shield (continued)

the leveler door port. This smoke boot is connected to a spillage chute which conveys the excess coal from leveling into an existing receiving hopper. The smoke boot and chute system were designed to minimize the release of coal dust.

Leveler Bar Relocation

The maintenance of existing coke production rates necessitated that single spot pushing and leveling be used. This required relocation of the leveler bar to a position two oven center-line distances away from the ram.

Leveler Door Operation

An automatic door mechanism permits the pusher operator to open or close the leveler door from within the operator's cab. The required movements are powered by three air-operated cylinders as shown in Figure 23. All oven doors were provided with a new type of leveler door (Figure 24) designed for improved self-sealing and having a cam type latch designed for operation with the new air powered door operator.

Electrical Equipment

Electric control equipment was furnished for:

1. Automatic operation of leveler bar
2. Automatic operation of leveler door
3. Signal system between pusher and larry car.
4. UHF alignment interlock - transmitter
5. Voice communication equipment.

BATTERY MODIFICATIONS

Steam Ejector System

The success of the AISI/EPA coal charging system requires the use of a good steam aspirating system that will cause all the emissions to pass through the gas collecting main. Considerable work was done in the early phases of this test program in developing the requirements of such a system as described in

LEVELER DOOR OPERATOR

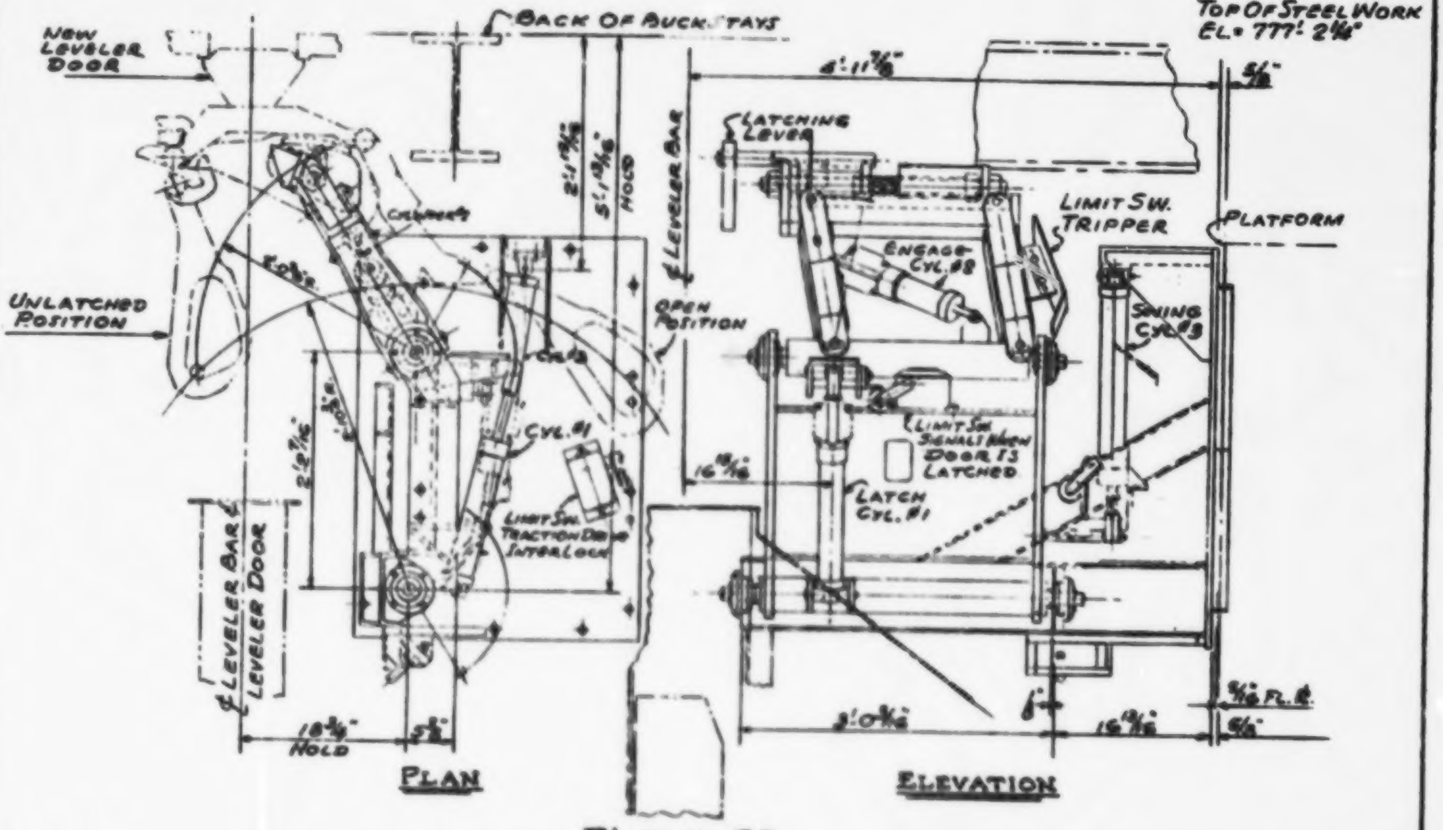
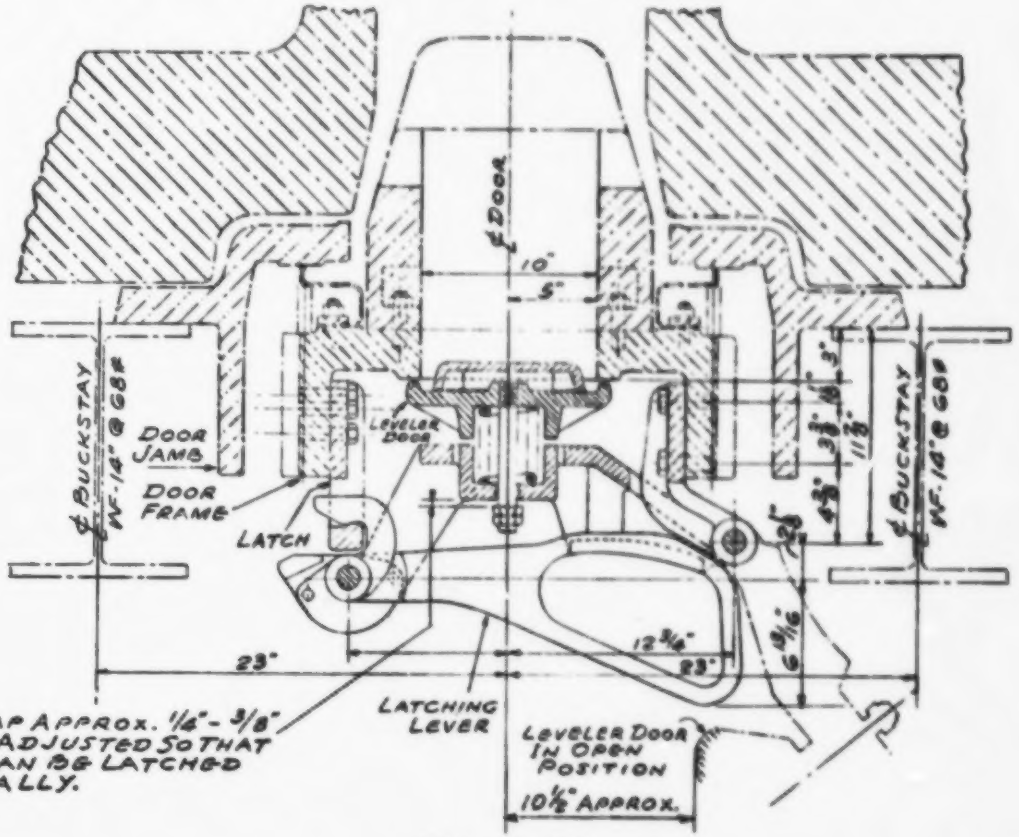

NEW LEVELER DOOR
UNLATCHED POSITION
BACK OF BUCKSTAYS
CRANK
2'-1 13/16"
5'-1 13/16" HOLD
℄ LEVELER BAR
OPEN POSITION
CYL. #2
CYL. #1
LIMIT SW. TRACTION DRIVE INTERLOCK
2'-2 7/16"
℄ LEVELER BAR ℄ LEVELER DOOR
18 3/4" HOLD
5 3/8"
PLAN
TOP OF STEEL WORK EL. 777'-2 1/4"
4'-11 3/16"
5/16"
LATCHING LEVER
LIMIT SW. TRIPPER
PLATFORM
ENGAGE CYL. #8
SWING CYL. #3
LIMIT SW. SIGNALS WHEN DOOR IS LATCHED
LATCH CYL. #1
16 13/16"
3'-0 3/16"
16 13/16"
9/16" FL. ℄
5/16"
ELEVATION

Figure 23

LEVELER DOOR



℄ DOOR
10"
5"
LEVELER DOOR
DOOR JAMB
DOOR FRAME
LATCH
℄ BUCKSTAY
WF-14" @ 68#
℄ BUCKSTAY
WF-14" @ 68#
3"
11 3/8"
4 3/8"
6 13/16"
12 3/4"
23"
23"
LATCHING LEVER
LEVELER DOOR IN OPEN POSITION
10 1/2" APPROX.
THIS GAP APPROX. 1/4" - 3/8" TO BE ADJUSTED SO THAT DOOR CAN BE LATCHED MANUALLY.

Figure 24

the report, "Ascension Pipe Steam Ejector Test Program" by John P. Connolly, dated September 14, 1970.[9]

The three main parts of a typical ascension pipe consist of the standpipe, gooseneck, and return bend. Figure 25 shows the existing arrangement on P-4 battery. The gooseneck section has an opening for cleaning and inspecting the unit which is sealed by the standpipe cap. It also has a steam nozzle which discharges toward the collecting main. This nozzle is installed so that it can be easily cleaned or replaced. The return bend has one or two ammonia liquor sprays which cool the gas and condense out the heavy tars. The return bend is sloped to allow the liquor to drain into the collecting main. A liquid sealed valve is placed at the end of the return bend and is used to damper off the gas collecting main.

The ascension pipe carries the gases generated during coking from the oven chamber into the collecting main which runs along the battery.

During charging when the evolution of volatile gases within the ovens is at a maximum rate, it is necessary to use aspirating steam to increase the gas flow through the ascension pipe.

A steam ejector can be defined as a device in which the kinetic energy of the steam is imparted to the raw oven gas in the ascension pipe to increase its velocity. The use of the steam acts like a pump to increase the gas flow.

Considerable testing was undertaken to analyze the performance of the existing steam ejector and several new designs. As a result of the test work briefly described in the section on Project Results (pg 161), it was determined that the existing design provided adequate ejector performance. Five ascension pipe gooseneck and return bend assemblies (Figure 26) having improved ejector characteristics were installed. This design featured improved spray location, smooth flow geometry, and a concentrically located steam nozzle. These assemblies were installed with 11/16" steam nozzles. The existing gooseneck assemblies were equipped with 3/4" nozzles to obtain equivalent suction capabilities.

ASCENSION PIPE ARRANGEMENT-EXISTING

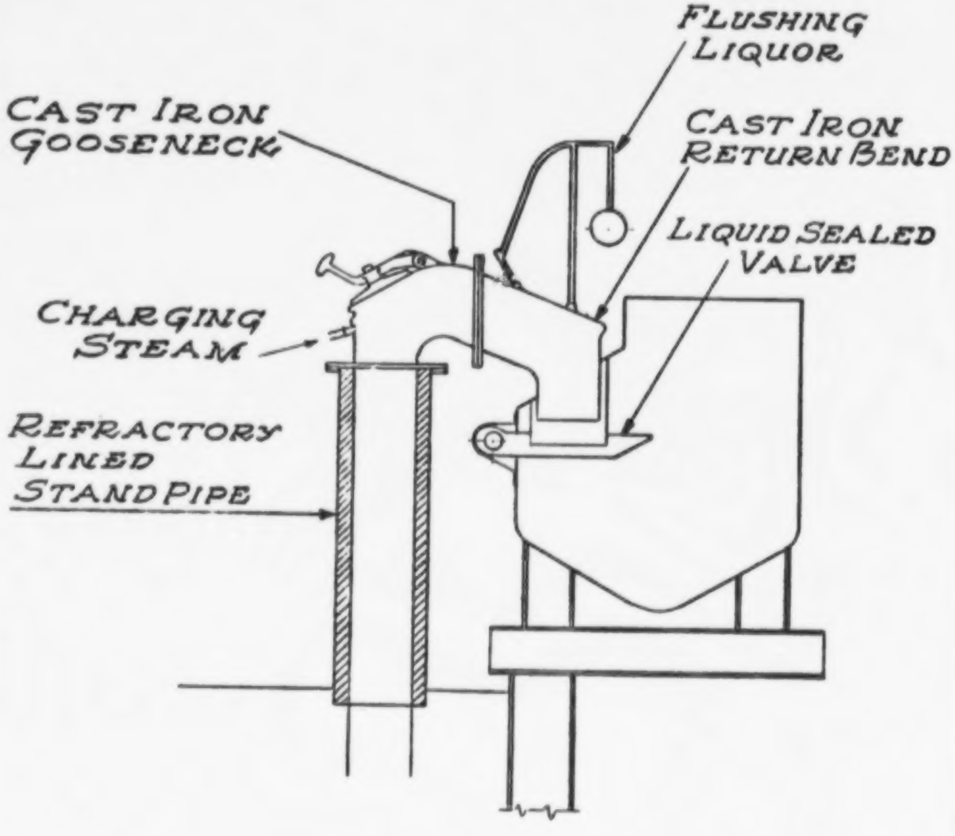

FLUSHING LIQUOR
CAST IRON GOOSENECK
CAST IRON RETURN BEND
LIQUID SEALED VALVE
CHARGING STEAM
REFRACTORY LINED STAND PIPE

Figure 25

NEW DESIGN ASCENSION PIPE

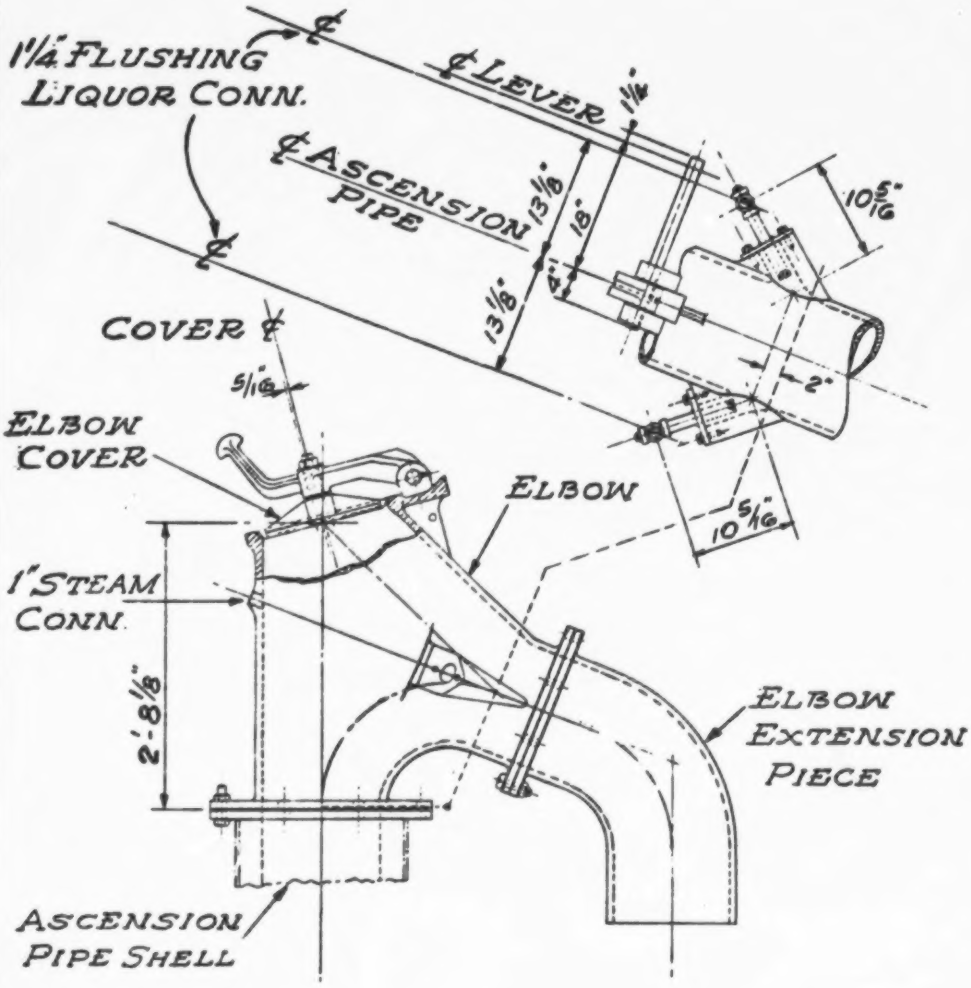

1¼" FLUSHING LIQUOR CONN.
℄
℄ LEVER
1¼"
℄ ASCENSION PIPE
13⅛"
18"
4"
13⅛"
10 5/16"
2"
10 5/16"
COVER ℄
5/16"
ELBOW COVER
ELBOW
1" STEAM CONN.
2'-8⅛"
ELBOW EXTENSION PIECE
ASCENSION PIPE SHELL

Figure 26

Steam Ejector System (continued)

As a result of the test work a high pressure steam line was constructed for use with a 180 psi, 475°F steam supply. A pressure reducing station was supplied so that the steam pressure could be varied. To minimize the effects of coal carry-over, the steam pressure just necessary to provide adequate suction would be used. The steam pressure is usually carried at 135-140 psi.

Another requirement of a good steam ejector system is a steam nozzle that will deliver the proper jet into the gooseneck to obtain optimum suction. It is important that the nozzle remain free of carbon deposits so that there is no interference with the steam jet that would change its direction or otherwise constrict it. Considerable work was done to develop a self-cleaning steam nozzle similar to that shown on Figure 27. These nozzles were installed on all goosenecks.

The addition of damper, steam valve, and standpipe cap operating linkages to each ascension pipe was previously described.

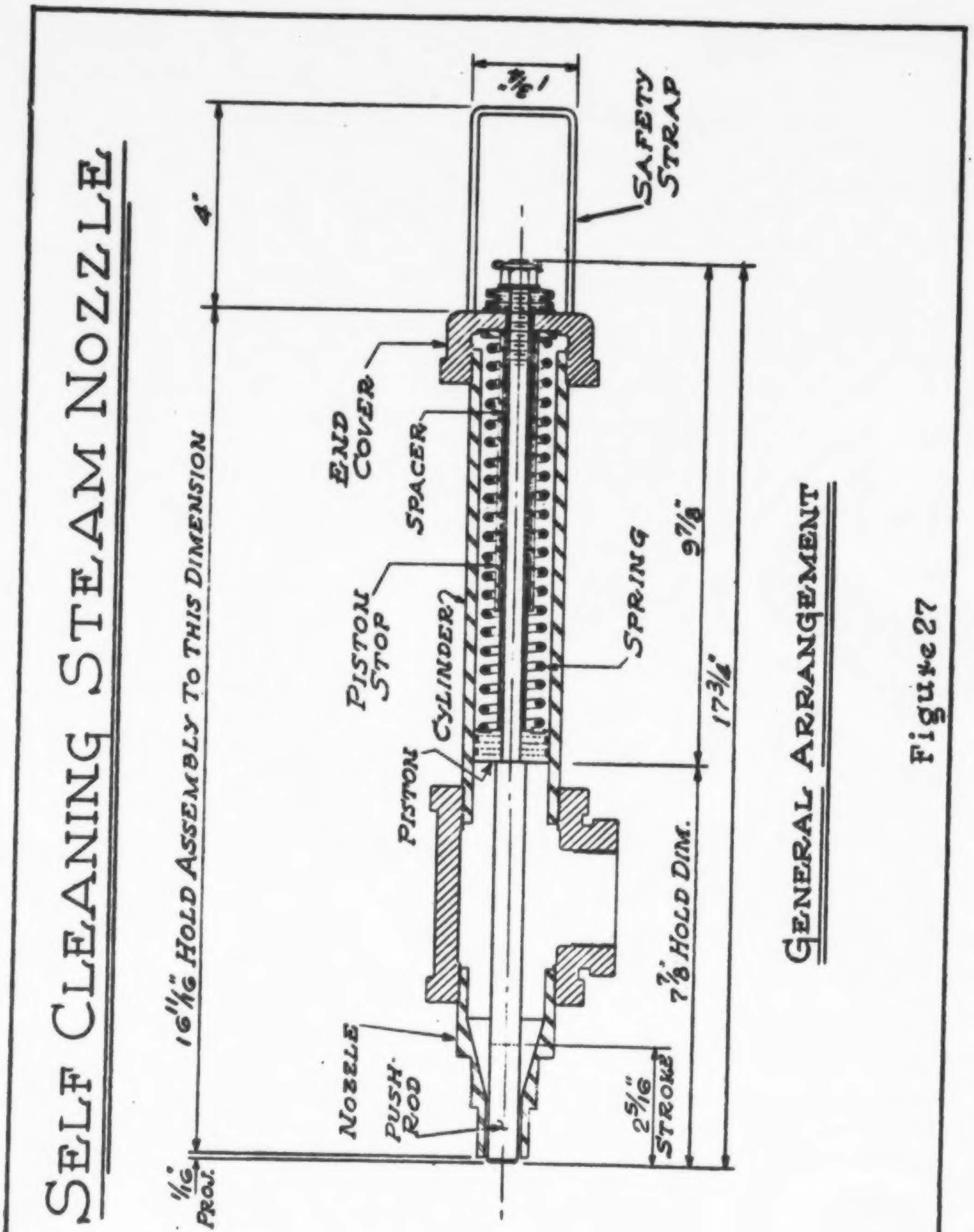
Charging Holes

New charging hole covers were installed on all charging holes designed for use with the automatic lid lifters. The design (Figure 28) incorporated radial grooves which permit positive engagement by pins on the lid lifter magnet to ensure oscillation of the lid. This oscillation is intended to cut carbon deposits on the ring surface, thus improving the oven port seal.

The lid was provided with three lugs which minimize the possibility of it tilting in case some one stepped on it.

Oven Alignment

The charging hole rings had to be re-located so that they were concentrically aligned with the larry car drop sleeves. Sufficient alignment was required to assure reliable seating of the sleeves within the rings.



SELF CLEANING STEAM NOZZLE

1/16" PROJ.
16 11/16" HOLD ASSEMBLY TO THIS DIMENSION
4"
1 3/8"
SAFETY STRAP
END COVER
SPACER
PISTON STOP
CYLINDER
PISTON
SPRING
NOZZLE
PUSH ROD
2 5/16" STROKE
7 7/8" HOLD DIM.
9 7/8"
17 3/4"

GENERAL ARRANGEMENT

Figure 27

CHARGING HOLE LID

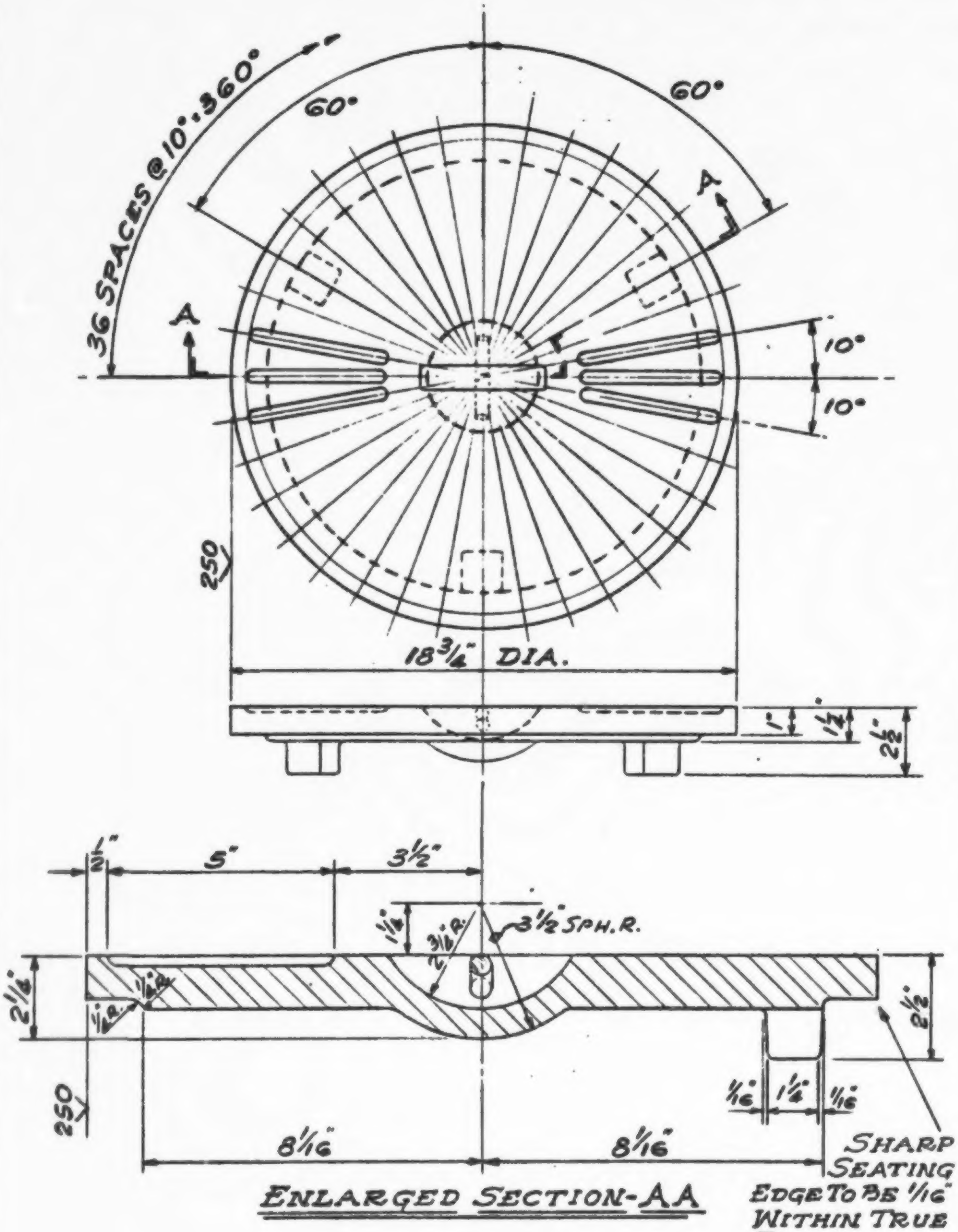

36 SPACES @10°=360°
60°
60°
A
A
10°
10°
250
18 3/4" DIA.
1"
1 1/4"
2 1/2"
1/2"
5"
3 1/2"
1 1/4"
3 1/16 R.
3 1/2" SPH. R.
2 1/8"
1/16 R.
1/16 R.
2 1/2"
1/16"
1 1/4"
1/16"
250
8 1/16"
8 1/16"
ENLARGED SECTION-AA
SHARP SEATING EDGE TO BE 1/16" WITHIN TRUE PLANE.

Figure 28

Oven Alignment (continued)

The mounting of a set of brass vanes at each oven was required to facilitate larry car positioning. The panels containing the vanes were mounted on cross members attached to the collector rail supports. It was necessary to reinforce the collector rail supports to assure a stable position.

Battery Reinforcement

It was necessary to reinforce portions of the battery to handle the additional weight of the larry car. The car weighs approximately 70 tons empty and about 87 tons full. Since this car is parked at the south end of the battery next to the existing spare larry car it was necessary to reinforce that end of the battery. Hydraulic bumpers were installed with a design rating equivalent to that necessary to stop the car at full speed.

The existing coal bin scale was removed because it could not handle the additional weight. It was necessary to improve the stability of the rails on the rail chairs by the addition of shims.

SECTION VI

PROJECT RESULTS - SMOKELESS CHARGING

CHARGING EMISSIONS

The application of this charging concept to a battery with a single gas off-take did not result in smokeless charging. Emissions were evaluated by visual observations based on the Ringelmann number range or the equivalent opacity. The detailed observation procedure is given in Appendix D. Some tabulated results are shown on Table 3.

During January and February, 1973, there were 236 charges observed representing the initial data for evaluation of emissions. The average results of these charges shown in Table 3 do not meet any of the acceptable criteria listed in Table 1 (pg. 4). There were 16 charges in January during which no T3 emissions occurred. The data for those charges is shown in Table 4. One obvious conclusion, after studying the available information for all 236 charges, is that the cause of the variable results is not apparent from the data. Some of the best charges shown in Table 4 occurred in spite of unfavorable conditions such as:

1) Failure of a drop sleeve to seat
2) Constrictions in ascension pipe (carbon deposits)
3) Standpipe cap leaking
4) Heavy flare carbon in charging holes

Table 3. LARRY CAR CHARGING EMISSIONS

(Single gas off-take)

Measured Parameter Seconds	Jan/Feb 1973 236 chg.	April 1973 125 chg.	December 1973 5 charges P-4 pusher	December 1973 5 charges P-3 pusher	January 1974 10 charges 8.3% moisture
Avg. charge cycle time	227.6	273.5	258.6	293.6	235.5
Avg. charge time	172.4	173.0	149.8	178.2	193.9
Avg. T0	54.4	75.1	68.8	47.2	70.1
Avg. T1	99.1	140.3	85.6	99.2	82.9
Avg. T2	24.4	21.8	71.0	94.4	38.4
Avg. T3	50.3	36.3	37.0	52.8	51.4

Charge Time = Interval from start of coal charge till final coal feed (last butterfly closed)

Definition of remaining terms shown below Table 1, page 4.

CHARGING EMISSIONS (continued)

It was established that the emissions occur while leveling during the final 20% charge, and also during the re-lid cycle. Three factors indicated that this problem was not the result of insufficient oven suction.

1. Prior to the start of leveling, the oven suction created with 130-140 psi steam is sufficient to prevent emissions if the components of the charging system are in reasonable working condition.

2. The emissions do not appear to generally occur just from the use of the leveler bar, but rather from a combination of its use and a coal peak under one of the charging holes. The occurrence of emissions can usually be associated with slow coal feed from one of the hoppers indicating that coal is backed up in the charging hole and must be removed by the leveler bar.

3. Improving the oven suction by increasing the steam pressure will not necessarily result in less emissions. Table 5 shows the results of observed charges (February 5, 6, 7) in which the steam header pressure was changed during part of each day. The average time of T3 emissions is greater for those charges made with the high pressure steam. Since it is known from test work that oven suction at 180 psi is greater than that which occurs at 140 psi, the results of the data in Table 5 are misleading.

These observations and data led to the conclusion that the principal cause of emissions was the result of not maintaining an open gas passage at the top of the oven.

STEPS TO IMPROVE CHARGING PERFORMANCE

Step 1 - Automate Leveler Bar Stroke

The operation of the leveler bar was under the control of the pusherman. Accordingly the cycling of the leveler bar was not consistent and depended on the experience of each operator. This particularly affected the coal being leveled under #3 charging hole. If the bar was not extended fully each cycle, or if

Table 4. LARRY CAR CHARGING EMISSION DATA
(16 best charges - January 1973)

Date	Oven No.	TO (Sec.)	T1 (Sec.)	T2 (Sec.)	Chg. time (Sec.)	Chg. cycle time (Sec.)	Principal source of emissions	Unfavorable system conditions
1-5	2-20	72	100	19	120	191	#2 D.S. Seal	
1-5	3-20	37	130	21	159	188		#1 D.S. 2" Open,Seated with Vibrator
1-5	2-22	99	166	23	196	288	#2 D.S. Seal	#1, 2 Charge Hole Heavy Flare Carbon
1-5	3-18	125	117	08	145	250		Constricted Gooseneck,Standpipe Cap Leaked
1-5	2-14	207	69	10	177	276	#2, 3 D.S. Seal	#2 D.S. 1/4" Open,Standpipe Cap Leaked
1-5	3-14	242	46	07	207	295	#1 D.S. Seal	#1 D.S. 2.5" Open
1-5	3-16	177	58	03	171	238	#2 D.S. Seal	#1 D.S. 2.5" Open,Standpipe Cap Leaked
1-16	1-13	104	66	19	124	189	#2 D.S. Seal	#3 D.S. 0.5" Open
1-16	2-13	132	63	49	134	244	#2 D.S. Seal	#2, 3 Charge Hole Carbon,Constricted Standpipe
1-16	1-15	106	58	13	132	177	#2 D.S. Seal	
1-18	2-22	159	130	11	265	300	#2 D.S. Seal	#1, 2 Charge Hole Heavy Flare Carbon
1-18	3-22	132	130	18	228	280	#2, 3 D.S. Seal	#3 D.S. 1" Open
1-18	2-20	92	116	32	153	240	#2 D.S. Seal	
1-18	1-22	122	188	10	207	320	#1, 3 D.S. Seal	#2 Charge Hole Heavy Flare Carbon
1-22	3-18	97	44	27	113	168	#3 D.S. Seal	#2 Charge Hole Carbon,Gooseneck Constricted
1-29	2-10	15	185	07	163	207	#2, 3 D.S. Seal	#2 D.S. 4" Open,Gooseneck Constricted
Avg.		119.9	104.1	17.3	168.4	240.5		

D.S. - Drop Sleeve

Table 4. (continued) LARRY CAR CHARGING EMISSION DATA

Date	COAL ANALYSIS							WEATHER CONDITIONS					
	Wt/Ft^3	% Vol. matter	% Moist.	% Fixed carb.	% Ash	% Sul.	Oil Pt/ton	Temp. ^oF	Wind vel. mph	Atm. Press.	Precip.	% Humid	Atm. cond.
1-15	43.4	32.26	7.0	60.15	7.59	1.24	3.42	44.5	6	29.73	----	72	Overcast
1-16	43.66	32.24	7.39	60.1	7.66	1.24	3.47	40.0	15/SW	29.50	----	70	Sunny
1-18	43.83	32.28	7.23	59.8	7.92	1.24	3.38	64.0	11/W	29.12	----	38	Clear
1-22	41.28	32.23	8.25	60.05	7.72	1.23	3.35	62	7/SSE	30.31	----	45	Sunny
1-29	43.10	32.26	7.0	59.89	7.85	1.22	3.38	30	6/NNW	29.62	Snow	84	Overcast

Notes 1 #2 drop sleeve seal at charging hole ring was a principal source of emissions 69% of the time.

2 Five occurrances of poor drop sleeve seating with 1" or more air gap.

3 Six occurrances of extra heavy flare carbon in charging holes.

4 Three occurrances of a constricted gooseneck or standpipe.

5 Three cases of standpipe cap leakage.

6 Steam pressure was 140 psi and steam temperature was 450°F for all charges except on January 29: 170 psi and 510°F.

Table 5. LARRY CAR CHARGING EMISSIONS
VARIABLE STEAM PRESSURE

(Single gas off-take)

Measured parameter time in seconds	Steam header pressure	
	180-190 psi	140-150 psi
No. of charges	46	42
Avg. charge cycle time	224	234
Avg. charge time	169	172.5
Avg. T0	48.3	48.2
Avg. T1	86.4	104.1
Avg. T2	25.3	26.8
Avg. T3	63.8	55.0

Definition of terms shown in Glossary, page 198.

Step 1 - Automate Leveler Bar Stroke (continued)

an excessively long stroke was used, the coal leveled at #3 would be significantly less that at #1 or #2. The worst source of emissions frequently occurred at #3 charging hole, particularly when #3 hopper was the last one to empty.

The operation of the leveler bar was automated so that a consistent repeatable stroke would be used, thus eliminating this factor as a variable. The leveler bar stroke was set at 9 feet to provide maximum leveling at #3 charging hole.

Step 2 - Increase Gas Passage Space During Leveling

The original leveler bar had baffles between the side plates spaced at 33" intervals. These baffles move the coal during the leveling operation. The top of the baffle was about 3/4" below the top of the side plate. The oven roof is approximately 2" above the leveler bar. The presence of roof carbon could seriously affect any available gas passage during leveling.

The tops of the baffles were cut 2-3" to increase the available gas passage. The 3" cut was made on those baffles occurring more than 20' back from the leveler bar nose. The number of baffles was doubled so that the coal would be moved at least as effectively as before.

It was necessary to add a chain to clean the tops of baffles when the leveler bar was withdrawn from the oven in order to prevent a build-up of carbon.

Step 3 - Leveler Door Closed Prior to Lidding

It had been observed that emissions occurred during the sequential re-lidding of oven ports prior to closing the leveler door. The smoke seal at the leveler door was not tight enough to prevent emissions with one charging hole open. At the expense of increased charging cycle time, the emissions during re-lidding could be virtually eliminated by closing the leveler door first.

Step 4 - Slow Down Final Coal Feed

The rate at which coal is charged into an oven greatly exceeds the rate at which it can be leveled. To an order of magnitude approximation, a feed rate of 2.5 Ft^3/sec. would exceed the leveling rate by a factor of 3 to 5.

There is no readily available means to vary the coal feed rate during charging. In general the coal feed rate will decrease with an increase in the butterfly oscillation angle. To a lesser extent a lower setting of the hydraulic flow control valve will decrease the feed rate for the larger oscillation angles (more than 60°) by slowing down the oscillation rate.

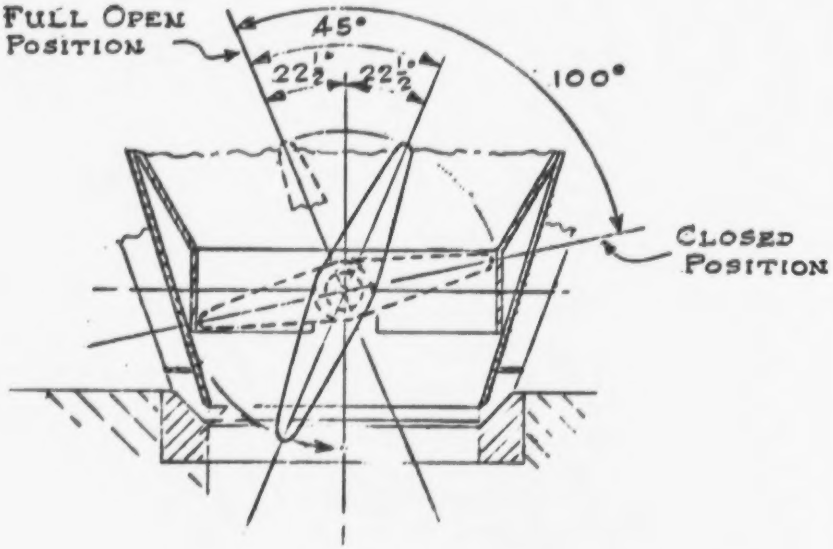
The angle of oscillation used with this feed system is approximately 45°. The most effective way to slow down the coal feed was to increase its oscillation angle during leveling. The control system was modified so that when the coal reached the 75% level, the butterfly valve oscillated between full open and full closed position. This arrangement is shown on Figure 29. This accomplished a slow down in the final feed rate. However it also resulted in more occurrences of packed coal during leveling, which resulted in a stalled butterfly valve. During leveling the coal will back up into a charging hole as shown in Figure 5 (pg.21) for #2 charging hole. As this coal backs up, the cyclic closing of the butterfly valve during the final coal feed has a tendency to pack the coal in the lower portion of the drop sleeve. Consequently this procedure was abandoned and the oscillation angle now remains constant during the entire charging interval.

REDUCTION IN CHARGING EMISSIONS

The results of these four modifications appear in Table 3 for 125 charges made in April 1973. The average charge time was unchanged. The charge cycle time increased 46 seconds as a result of closing the leveler door prior to re-lidding. The incidence of T3 emissions decreased 28%, and that of T2 emissions by 10%.

The significant improvement over previous results is attributed to the early closing of the leveler door and the use of automatic leveling. The modification to the leveler bar baffles is believed to have helped, but its effect was not easily measured. The

BUTTERFLY OSCILLATION ANGLE


FULL OPEN POSITION
45°
22½°
22½°
100°
CLOSED POSITION

NORMAL OSCILLATION ANGLE OF 45° SET BY ADJUSTABLE PROXIMITY SWITCHS.

FINAL OSCILLATION ANGLE OF APPROXIMATELY 100° DETERMINED BY FULL OPEN AND CLOSE POSITIONS.

INITIATION OF LARGE OSCILLATION ANGLE OCCURS WHEN COAL LEVEL SENSOR DETERMINES THAT 75% COAL CHARGE IS COMPLETE.

Figure 29

increased opening above the baffles reduced the effectiveness of the leveler bar smoke seal. As previously indicated the butterfly angle of oscillation was restored to a constant 45° to minimize coal packing in the drop sleeve.

The improved charging procedures did not solve the major problem of maintaining an open gas passage at the top of the oven.

Additional data is shown on Table 3 for five charges made in December, 1973 with coal having a typical 7% moisture utilizing automatic leveling with P-4 pusher. This represents the best results that can be expected with this charging system.

OVEN PRESSURE DURING CHARGING

This charging system has not achieved low oven pressure during the entire charging cycle. On an oven with good aspiration and with consistent coal flow from all three hoppers, the pressure at the smoke hole (coke side of the oven) when measured has typically averaged -1" to +1" w.c. from the start of the charge through the initial period after leveling starts. Approximately 5-8 seconds after the final feed starts, the oven pressure at the smoke hole typically increases to +8 or +10" w.c. As soon as the coal feed is complete and the butterfly valves are closed, the oven pressure decreases. The period of unacceptable emissions corresponds to the time representing the final 20% coal feed during which time leveling occurs. The increase in pressure at the coke side smoke hole verifies the constriction of the gas passage at the top of the oven. Details on pressure measurements are given in Appendix A, complete with a pressure recording.

The average performance can be somewhat improved by initiating leveling at the start of the charge. This improvement is the apparent effect of distributing the coal charge more uniformly in the oven so that an increased gas passage space exists at the top of the oven for a given amount of coal charged. Although this method will typically reduce emissions, it still does not produce a smokeless charge. It has one serious drawback. If the coal does not start flowing from all hoppers at the start of the charge, the leveling time will be excessive. The excessive exposure of the leveler bar in the oven can result in it being overheated. Consequently this method is not recommended as a production procedure with the present leveler bar.

ANALYSIS OF THE PROBLEM

The reason why it is not possible to get consistent smokeless charges can best be understood by a review of the method for assuring an open gas passage during charging. To maintain an open passage, it is necessary that the coal charged in any given port does not back up inside the charging hole sufficiently to form a block. The chances of doing this are minimized if the coal to be leveled is shared at all three charging holes. Prior to leveling, the coal should be poured at proportional feed rates that will result in uniform peaks near the coal level line (Figure 30).

At this time about 76% of the charge is in the oven. As coal feed resumes the leveler bar will distribute the coal. When approximately 91% of the coal is in the oven and leveled, the flat tops will extend about one foot past the charging hole flare opening. At this time the approximate remaining average coal charge per hopper is 21 ft^3 including all coal in the charging hole flares and the leveler bar. As a consequence the gas passage is constricted and internal pressure starts to build-up. It is desirable that this portion of the charge be completed as soon as possible to minimize emissions.

With optimum coal flow conditions, there will probably be some emissions associated with the last half of the leveling cycle. The quantity of emissions will be influenced by the required leveling time and the quantity of roof and flare carbon within the oven.

The smokeless charges that have occurred are generally the result of slight undercharging, uniform coal feed, minimal roof and flare carbon, and adequate suction.

If the coal feed pattern from the three hoppers is not relatively uniform, excessive leveling will be required at one

OVEN COAL PROFILE DURING CHARGING

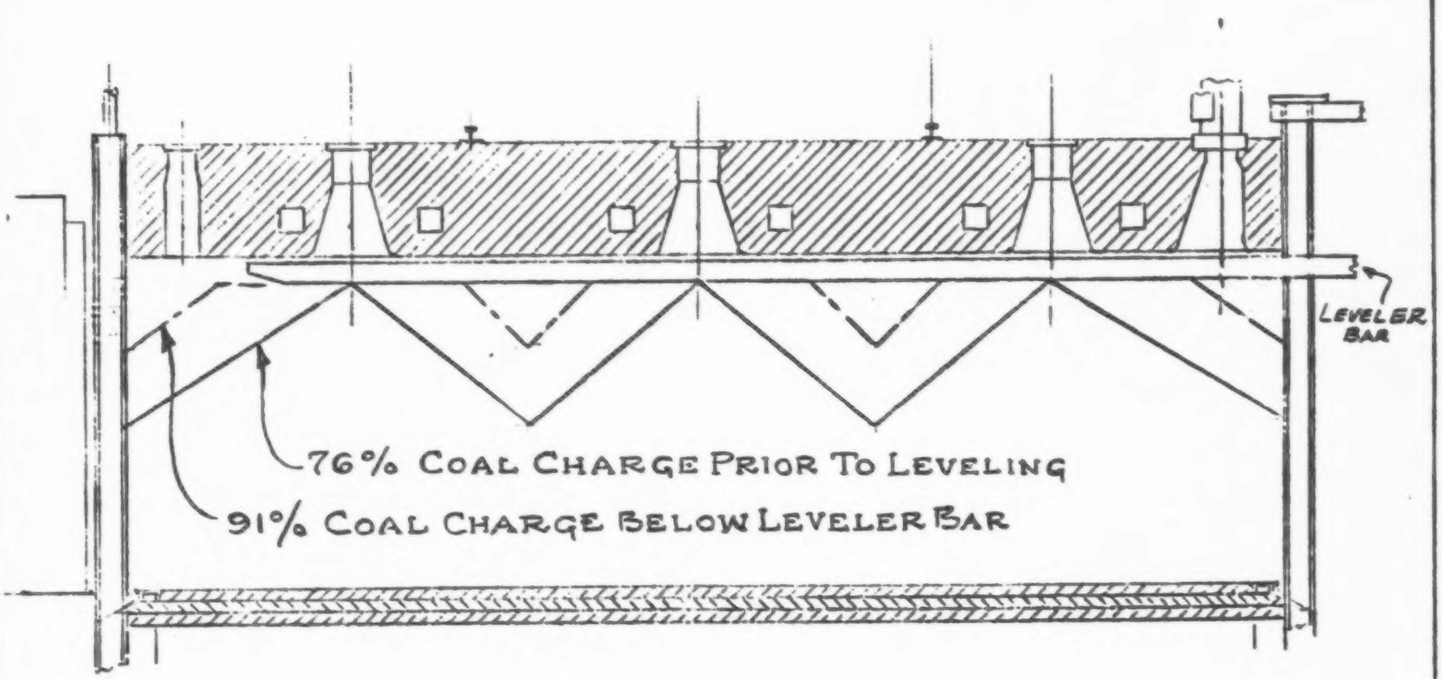

LEVELER BAR
76% COAL CHARGE PRIOR TO LEVELING
91% COAL CHARGE BELOW LEVELER BAR

Figure 30

charging hole (the one with the slow feed). This increases the leveling time during which the gas passage is constricted. It also increases the length of the constricted gas passage.

SUMMARY OF RESULTS

This test program has demonstrated that with all components functioning as designed the emissions cannot all be directed into the gas collecting main on a consistent basis, under the following conditions:

1. Using the maximum acceptable amount of oven suction as generated by the aspirating steam system.

2. A single gas outlet from the oven to the gas collecting main.

3. With gas flow constrictions resulting from coal flow and the presence of the leveler bar in the oven during the final coal charge.

The experience of charging with this coal feed system indicates that the relative feed rates among the three hoppers cannot be controlled consistently to minimize leveling. Refer to the emission data sheets for December in Appendix D. A procedure is necessary that does not require consistent coal feed rates to minimize constriction of the gas flow within an oven.

SOLUTION

To approach consistent smokeless charging conditions, it is necessary that this system be modified by the addition of a second gas off-take at each oven. A double gas off-take provides the means for assuring an open gas passage at the top of the oven.

J&L has investigated methods for reducing emissions on other batteries at the Pittsburgh Works. This included the installation of "jumper pipes" connecting the smoke hole ports of adjacent ovens. The smoke hole can be seen in Figure 5. It is located on the coke side of the oven and has the appearance of an outlet to a second collecting main. The addition of the jumper pipe

SOLUTION (continued)

provides a second gas off-take from the oven, by permitting gases from the oven being charged to reach the gas collecting main through an adjacent oven (Figure 31). During charging, in addition to the normal procedures in placing the oven "on-the-main", the jumper pipe is opened and the aspirating steam is also turned on at the adjacent oven. Since this adjacent oven is well into the coking cycle, it can handle the charging gases from the coke side of the oven in addition to its own coking gases.

Two such jumper pipes were recently installed on oven 1-1 and 1-2 on P-4 battery. The arrangement of these jumper pipes can be seen in Figure 32. Charges made on these ovens have resulted in emissions that exceed smokeless charging conditions for an average of 8.4 seconds. The average results of 15 charges are shown in Table 2 (pg.6). The data for 10 of those charges are part of Appendix D.

It is apparent from the data that the cycle time of charges with jumper pipes equaled or bettered the fastest charging times obtained with a single gas off-take. The actual time for the coal feed increased slightly. This was the result primarily with experimenting with different coal feed sequences. The charging results have not been significantly affected by the different coal feed procedures. Consequently it is believed that emptying the hoppers simultaneously will result in emissions that will equal the average shown on Table 2. With this method of coal feed a charging time of about 2.4 minutes can be realized with normal coal flow.

The charge cycle time is decreased because the charging holes can be sequentially relidded smokelessly without waiting for the leveler door to be closed.

As a result of test work on the single gas off-take system, and observations using the double gas off-take ("jumper pipes"), it is recommended that a double gas off-take be used to provide the adequate control of oven pressure necessary to ensure the success of this concept.

The required elements of this charging system to adequately

SOLUTION (continued)

control oven pressure are as follows:

1. Double gas off-take
2. Adequate steam aspirating system
3. Sealed oven ports
4. Controlled coal feed system
5. Sequential relidding of oven ports

THE EFFECT OF PROCESS VARIABLES ON EMISSIONS

Steam Pressure and Temperature

The relation of steam pressure to emissions during charging

JUMPER PIPE CHARGING

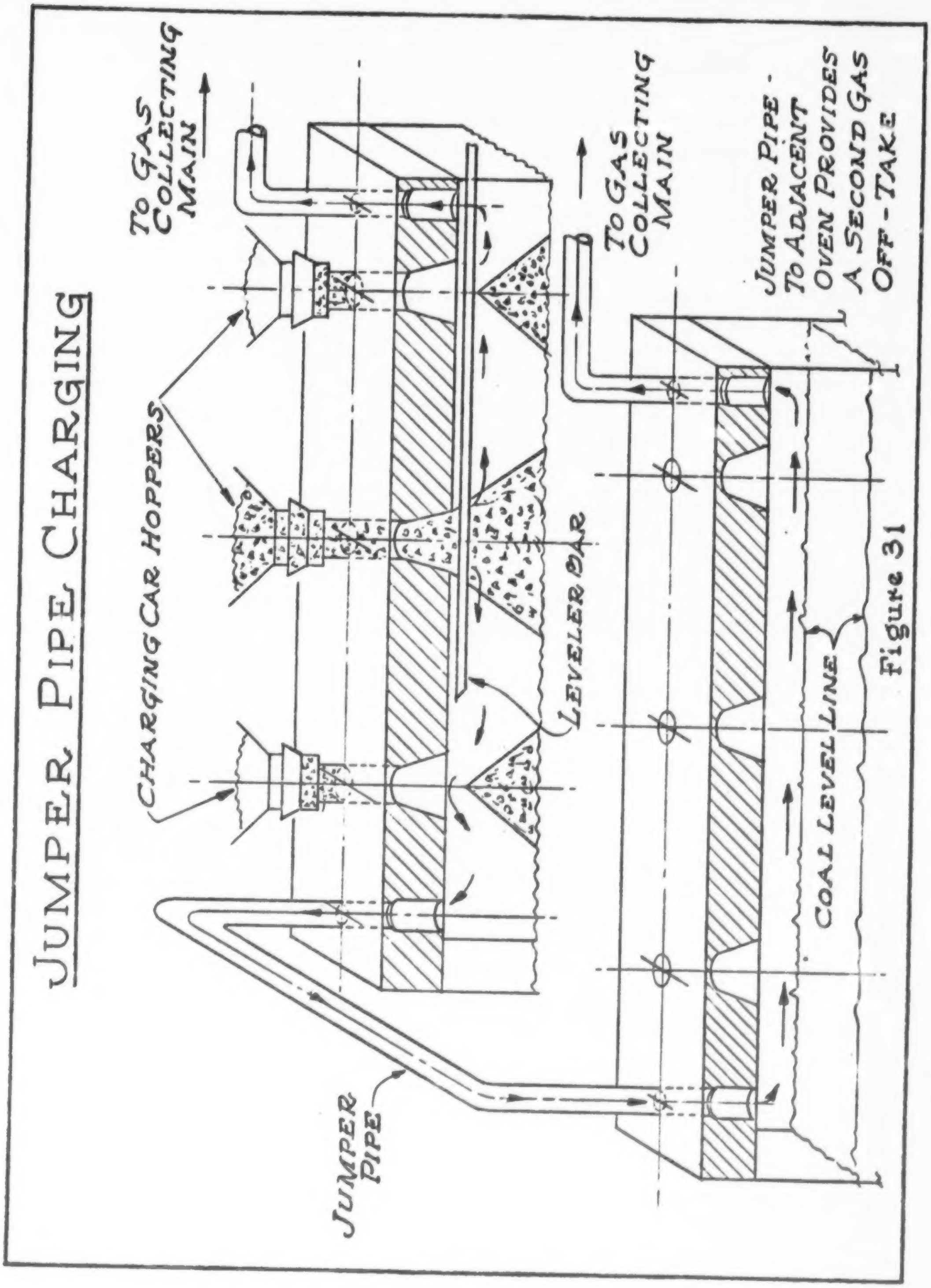

CHARGING CAR HOPPERS
TO GAS COLLECTING MAIN
LEVELER BAR
TO GAS COLLECTING MAIN
JUMPER PIPE
COAL LEVEL LINE
JUMPER PIPE - TO ADJACENT OVEN PROVIDES A SECOND GAS OFF-TAKE

Figure 31

JUMPER PIPE ARRANGEMENT

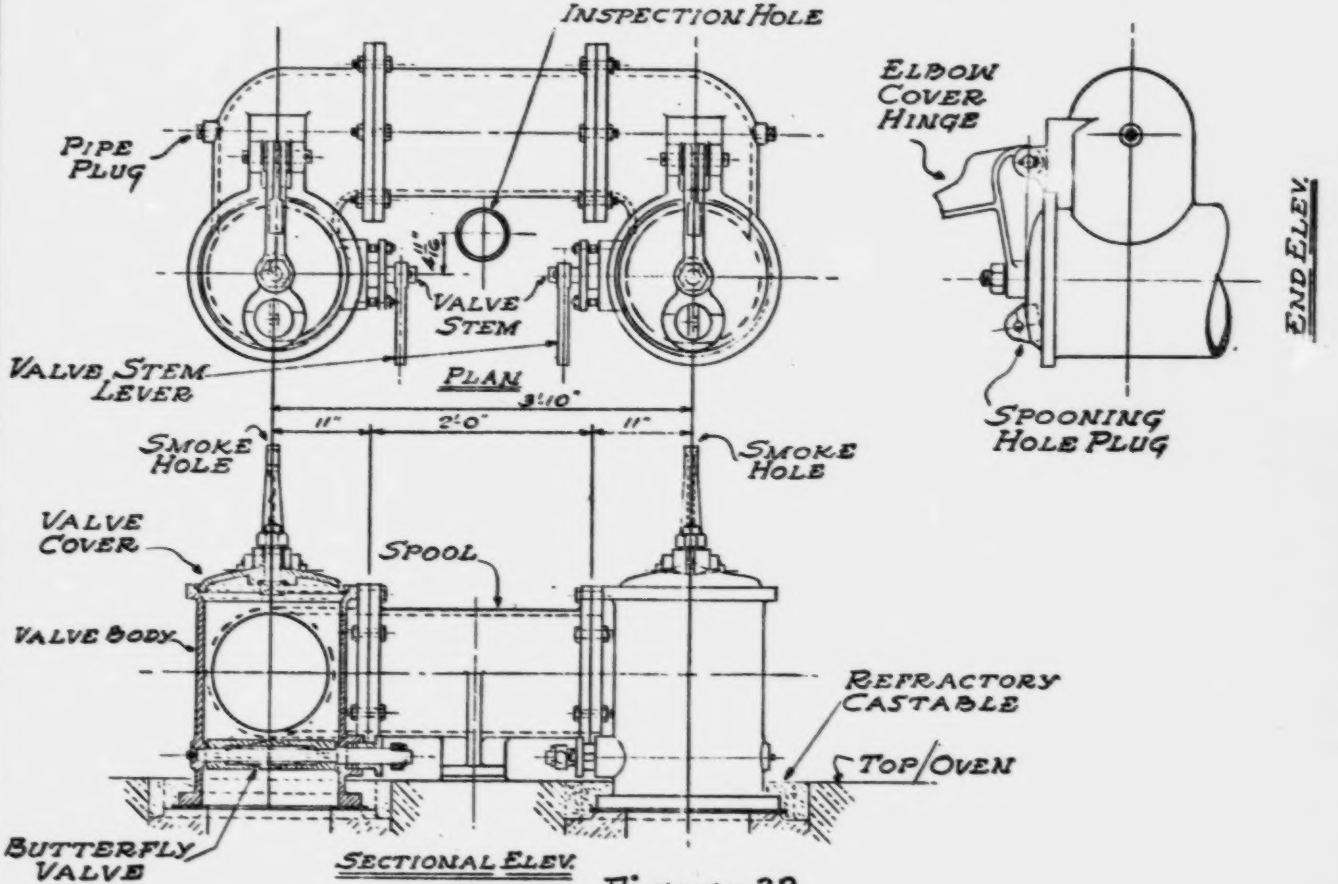

INSPECTION HOLE
PIPE PLUG
ELBOW COVER HINGE
VALVE STEM
11/16"
VALVE STEM LEVER
PLAN
3'10"
11"
2'0"
11"
SMOKE HOLE
SMOKE HOLE
SPOONING HOLE PLUG
END ELEV.
VALVE COVER
SPOOL
VALVE BODY
REFRACTORY CASTABLE
TOP/OVEN
BUTTERFLY VALVE
SECTIONAL ELEV.

Figure 32

Steam Pressure and Temperature (continued)

was difficult to determine on normal charging of ovens with a single gas off-take. This is demonstrated by the results shown on Table 5 which are discussed on page 71. The previous discussion has indicated how the constriction of the gas passage during leveling was the major factor in determining the quantity of emissions. Increased emissions can normally be observed when the header steam pressure is less than 120 psi.

The increased aspiration results in more coal carry-over into the gas collecting main. Prior to the installation of the new larry car some rough measurements were made using a temporary high pressure steam line and compared to that existing at the lower steam pressure level. The greater aspiration was the result of increasing the steam nozzle from 1/2" to 3/4", increasing the steam header pressure from 100 psi to 175 psi, and increasing the diameter of branch piping from 3/4" to 1 1/4". The method used to measure the coal carry-over is outlined in Appendix G. The results of all testing indicate that the carry-over during charging increased by a factor somewhere between 3:1 and 6:1.

The results (Appendix G) of collecting ammonia liquor samples from the gas collecting main just downstream verifies an increase in coal carry-over with the new larry car.

Coal Analysis and Moisture Content

The analytical properties of the coal had no apparent significance on the quantity of emissions during charging. The constriction of the gas passage during leveling made it difficult to determine the extent to which coal analysis contributes to charging emissions.

The moisture content of the coal did have an affect on the quantity of emissions. The results of 10 charges made in January 1974 with coal having 8.3% moisture can be compared with the normal results obtained from five charges in December 1973 using P-4 pusher in which the coal moisture was 7.1% The wet coal prevented uniform coal flow. Only 40% of the charges had normal charging times. The operator used a bar on at least one drop sleeve to get the coal flow started on six of the ten

Coal Analysis and Moisture Content (continued)

charges. The average charging time increased 30% and T3 emissions increased 40%. At the same time T2 emissions decreased 45%. The overall increase in emissions is attributed to longer required leveling time as a result of irregular coal feed.

Effectiveness of Oven Port Seals

A poor leveler door seal will cause increased emissions from the charging hole ports as well as the leveler door during the final 20% charge. It also causes emissions during the first portion of the charge.

Poor seating of the feed hopper drop sleeves will leave an open gap in part of the charging hole ring. During the last 20% of the charge, the positive oven pressure produces flames which damage larry car equipment.

Type and Condition of Ascension Pipe

There are two types of goosenecks used on this battery. Their characteristics are described in the section on Charging Equipment Description, (page 62). The gas flow characteristics from the two different designs tends to be about the same, since the conventional gooseneck has a larger steam nozzle.

The conditions of the standpipe, gooseneck, and steam nozzle limit the performance of the gas aspirating system. The steam nozzle must be clean and free of carbon deposits that constrict the path of the steam jet in the gooseneck. The ascension pipe must remain relatively free of carbon deposits. Constrictions near the top of the standpipe limit the suction more than those at the bottom. Less than 80% opening at the top or 50% at the bottom will usually result in a visible increase in emissions.

Similar changes are noticed when the gooseneck or return bend opening is less than 80%.

The standpipe cap must have a good seal to assure good steam aspiration. Any air drawn in at this source will reduce the oven gas flow through the standpipe.

Coal Charging Time and Charge Cycle Time

The coal charging time starts when the butterflies first open and oscillate. It ends when the last butterfly valve closes the final time. This time is directly related to the coal feed. In general the shorter times occur when uniform feed conditions exist on all three hoppers. Coal moisture will cause the charging times to increase, but if the rate of feed remains uniform in the three hoppers, this increased time will usually not result in more emissions. If the increased time is caused by non-uniform feed conditions between hoppers, then emissions are expected to increase. This is the result of increased leveling time during which severe gas passage constrictions cause increased oven pressure.

The charge cycle time includes the time required for closing all oven ports in addition to the charging time. The charge cycle time starts at the same time as the charging time and ends after all oven ports have been closed. With good charging conditions, the emissions in re-lidding are not significant. The emissions that normally occur in the last 20% coal feed are reduced as soon as all butterfly valves are closed. If significant emissions occur at the end of a charge, they are apt to continue while the leveler door is being closed. Once the leveler door is closed re-lidding of charging holes is usually performed without significant emissions, except for conditions of very poor oven suction or a constricted gas passage resulting from insufficient leveling.

Removing the leveler bar and closing the leveler door takes about 50 seconds. Sequential re-lidding of charging holes (1-2-3) takes 12 seconds each for the first two and about 18 seconds for the final one. The first two re-lidding operations require 12 seconds to replace the lids and start oscillating. The next re-lid sequence can be initiated at this time. The final re-lid sequence requires the lid lifter cycle to be complete before moving the car.

Weather Conditions

The weather conditions have little direct relation to the

Weather Conditions (continued)

charging performance with respect to emissions. To the extent that it affects the coal moisture, it is a determining factor.

There have been additional problems when the larry car is first placed in service during wet weather. The wet hoppers and drop sleeves cause irregular coal feed for the initial two or three charges.

The visual determination of charging emissions is influenced by background light and wind velocity.

System Malfunctions

Any failure with charging equipment that adversely affects the oven port seals, coal feed, maintenance of open oven gas passage, oven suction or proper re-lidding will tend to increase emissions. Good consistent charging requires reliable operation of equipment.

SECTION VII

PROJECT RESULTS - PROCESS CONTROL

COKE PRODUCTION

The charging system is designed to perform consistently without any reduction in coke production rates. The general criteria are to satisfy a pushing schedule of 60 ovens over an eight hour period. P-4 Battery has a maximum pushing capability of 40 ovens during an eight hour production turn. This is an average total charging cycle time of 12 minutes.

The following charging time log is typical of the results expected with the following conditions:

1. Single gas off-take.

2. Poking of coal with a steel rod not required to start and/or maintain coal flow.

3. Subsystems perform reliably with no malfunction.

	EVENT	ELAPSED TIME (MIN.)
1.	Start Charge (Oven 3-5)	0
2.	75% Charge Complete (#1, 2, 3) (Butterflies are Closed)	1.0, 1.1, 1.1
3.	Start Leveling	1.05
4.	Open Butterflies (Final 25% Charge)	1.25
5.	Hoppers Empty	1.75, 1.95, 2.1
6.	Request leveler Bar removed and Leveler Door Close	2.6
7.	Leveler Door Closed and Sequential Relid Starts	3.7
8.	Re-Lid Complete	4.55
9.	Complete Damper Off at Oven 3-9 and Remove Lids at Oven 3-7	5.55
10.	Get Coal at Bin and Move to Oven 1-7 (Typical Average)	8.05
11.	Manually Clean Gooseneck (1-7) and put Oven 1-7 on-the-main.	9.55

COKE PRODUCTION (continued)

These indicated total charging cycle times will not be attained if the coal does not flow properly from all hoppers. Poking of coal in the drop sleeve with a steel rod can result in an increased charging cycle time of one to three minutes. This problem, resulting from wet coal conditions, does not occur on every charge.

Typical times for such a case are as follows:

Event	Elapsed Time (Min.)
1. Start Charge	0
2. 75% Charge complete (#1, 2, 3)	1.0, 1.0, 1.85
3. Start leveling	1.05
4. Open butterflies (final 25%)	2.0
5. Hoppers empty (1, 2, 3)	2.3, 2.3, 3.6
6. Balance of event times normal	11.05

For this charge the coal did not start out of #3 hopper immediately and required the use of a coal poker. Apparently more of the coal from #2 hopper went to the coke side of the oven. Consequently considerable leveling was required to permit coal to discharge from #3 hopper. The coal actually backed up into #3 charging hole until removed by the leveler bar.

With a normal operating battery there are anticipated delays that must be incorporated in any over-all production schedule. Delays which affect pushing also affect the charging schedule, since the pusher machine may not be available when required for charging. These delays can be associated with equipment malfunctions, system problems (coke difficult to push from oven),or personnel breaks (eating lunch).

When equipment malfunctions occur, it may be quicker to repair the machine, rather than place a spare in service. At P-4 battery, it takes about twenty minutes to change the drop sleeve mounting position when transferring operation of the P-3 larry car from P-3 to P-4 battery or vice-versa.

A normal pushing schedule would anticipate delays of about 10% of the total operating time. An eight hour turn would achieve full production with about 48 minutes delay from all sources.

It is evident from the total charging cycle times indicated that the larry car can satisfy the schedule of 40 ovens per turn at P-4 battery. Recognizing 10% delays, the required total cycle time is 10.8 minutes or less. This compares well with the 9.55 typical total cycle time.

It is evident that this system as described for a single gas off-take system would not meet the requirements of an eight-hour pushing schedule of 60 ovens. Again recognizing 10% delays, the required total cycle time is 7.2 minutes or less. Since a double gas off-take is required to achieve an acceptable level of smokeless charging, the cycle time will be evaluated under these conditions. It must be recognized that the optimum charging procedure may not be determined until "jumper pipes" have been installed on the entire battery. Using the times required for re-lidding (does not wait for the leveler door to close) the following charging time log should be typical of good operating conditions. Events 6 and 7 are now performed in parallel and independent of the charging sequences.

Event	Elapsed Time
5. Hoppers empty	1.75, 2.4, 2.0
8. Re-lid complete	3.2
9. Complete damper-off	4.2
10. Get coal at bin and return to next oven	6.7
11. Manually clean gooseneck and put oven on-the-main	8.2

This total cycle time of 8.2 minutes will not satisfy the 60 oven pushing schedule where the corresponding time of 7.2 minutes or less is required. The problem in satisfying this schedule is not directly related to the actual charging sequence (3.2 minutes), but rather to the additional procedures involving "dampering off" and "cleaning goosenecks". If the lidman was used to "damper-off" (oven to be pushed) and "remove lids" (oven just pushed), the cycle time would be 7.2 minutes. An additional minute could be saved if the larryman cleans the gooseneck of the oven just pushed during charging. With either of these modifications to the system, a total cycle time of 7.2 minutes would be achieved permitting an eight-hour pushing schedule of 60 ovens.

BY-PRODUCTS

Directing all the charging gases into the collecting main by using greater oven suction may affect the by-products as result of

1. Increased gas in the system
2. Increase in coal carry-over
3. Increase in oxygen level
4. Increase of NO_x

The coke oven gas and tar were measured to determine the existance of any adverse changes in quality. One of the problems associated with oxides of nitrogen is the formation of gummy substances. The gum content of the circulating wash oil was monitored.

The by-product system receives the raw gas from five batteries, and the influence of P-4 battery on any changes to the system cannot be directly determined. "Jumper pipes" have been installed on the other four batteries to direct the charging emissions into the collecting main. Several tar samples were taken at #9 and #10 crossover, to monitor the tar from P-4 battery prior to reaching the decanter tanks.

TAR

Any increase in coal carry-over would be expected to show up in the tar processing system. The job of the "Tar-chaser" is to clean out the sludge from the gas collecting mains on a weekly basis. He has observed no change in the sludge taken from the collecting main at P-4 battery during the past year.

The sludge taken from the flushing-liquor decanter tank is reported to have increased about 15% during the past year. The pitch sludge buggies from each of five decanter tanks are emptied on a daily basis. During the past year the average sludge level in the buggies has increased about 2" - 3". This may also be partly the result of new conditions on the other four batteries.

Tests were performed at the P-4 battery cross-over to determine the effect of steam pressure on the amount of coal carry-over in the tar. Tar samples were collected for a 20-hour period with the aspirating steam pressure set at 130 psi. The samples were taken at a point at #9 cross-over just before it gets to the flushing-liquor decanter tank. Eight hour tar samples were then taken at 180 psi. The results are shown on table 6. The tar samples were examined under a microscope to determine the type and size of particles. The results (refer to Appendix G) show that the particles of coal, semi-coke, coke, and pyrolytic carbon (similar to wall and roof carbon) increased in quantity and particle size. The steam pressure is normally set at 130 psi - 140 psi at the header. The quinoline insolubles at 130 psi were about 20% greater than the 1968 average (100 psi aspirating steam pressure).

There has been no significant change in the by-product tar as measured at the tar pump after the ammonia liquor decanter tanks. The test results in Table 7 show no significant change from the 1968 average tar or the tests made in August 1972 just piror to the operation of the new charging system, and prior to the installation of jumper pipes on the other batteries.

Table 6. TAR SAMPLES P-4 BATTERY

(#9 Cross-over just ahead of decanter)

Measured Parameter	20 Hr. Sample 2/23/74	8 Hr. Sample 2/27/74
Steam pressure (psi)	130	180
Quinoline insoluble (% wt.)	8.9	11.5*
Benzene Insoluble (% wt.)	12.7	18.0
Ash (% wt.)	0.14	0.32
Coal Properties		
Bulk Density (lb/ft^3)	43.1	42.80
% Volatile Matter	32.25	32.27
% Moisture	8.01	8.51
% Fixed Carbon	60.65	60.50
% Ash	7.10	7.23
Oil pts./ton coal	2.8	2.8
Pulverization		
% on 3/4"	0	0
% on 1/2"	1.1	1.6
% on 1/4"	5.6	4.4
% on 1/8"	16.0	16.3
% through 1/8"	77.3	77.7
% through 100 mesh	10.6	10.6

* Coal evident in Quinoline Insolubles from this sample (180 psi)

Table 7. PRODUCTION TAR ANALYSIS

(Sampled after decanter)

Measured Parameter	Date					
	1968 Avg.	1972[a] 8/28–9/1	1972 10/17–10/28	1973 1/1 – 1/15	1973 5/14–5/31	1973 12/21–12/31
Specific gravity at 15.5°C	1.216	1.203	1.204	1.203	1.210	1.203
Engler viscosity at 140°C (sec.)	--	840	680.1	833.1	795	680
NH_4Cl (lbs/1000 gal)	2.0	2.4	1.7	3.1	5.8	3.6
H_2O (% vol.)	3.2	5.0	3.8	5.8	2.5	4.5
Distillate to 250°C (% wt, % vol.)	11.8/14.1[b]	13.3/15.6	14.6/17.4	13.8/16.4	15.7/18.7	14.5/17.3
Quinoline insoluble (% wt.)	7.1	7.6	6.9	7.7	6.7	8.0
Benzene insoluble % wt	10.5	11.3	10.3	11.7	10.2	11.0
Ash (% wt.)	--	0.047	0.013	0.04	0.06	0.045
Analysis-Dry tar basis						
Tar Acids (% wt., % vol.)	1.3/1.5	1.5/1.7	1.1/1.4	0.9/1.2	0.9/1.1	1.2/1.3
Tar bases (% wt., % vol.)	0.6/0.7	0.7/0.8	0.7/0.8	0.6/0.7	0.6/0.7	0.6/0.7
Napthalene (% wt., % vol.)	6.3/7.6	7.5/8.9	8.6/10.3	8.5/10.0	9.6/11.4	9.2/4.9
Creosote (% wt., % vol.)	4.2/5.0	4.3/5.0	4.9/5.7	4.4/5.2	5.6/6.2	4.1/4.9

a. Sampling performed just prior to start of new system
b. 11.8/14.1 is per cent by weight, then volume

COKE OVEN GAS

The quality of the coke oven gas (Table 8) has shown no significant change during the past year. The air content of the gas has increased (20-25%) as evidenced by an increase in nitrogen. This has probably contributed to a slight decrease in the BTU value of the gas.

The oxygen content of the coke oven gas from all five batteries has not shown any significant change during the past year.

Some oxygen sampling was performed on P-4 battery raw gas at each of two gas cross-over mains (#9 and #10). There were several samples in which the oxygen content exceeded 2%, with a maximum reading of 3%. The average value measured at the two cross-overs was slightly over 1.2%.

It should be noted in snap sampling that the oxygen content of the gas depends on local events on the battery that influenced a particular volume of gas. A second sample taken moments later could result in a dramatic change of oxygen content. The conclusions from all oxygen sampling are that the system has had no significant affect on the oxygen content of the coke oven gas at #9 and #10 crossovers. It must be recognized that the sampling was related to single gas off-take oven conditions, and that the addition of "jumper pipes" could alter the results.

The presence of increased oxides of nitrogen is not evident from tests made of the gum content of the circulating wash oil shown in Table 9.

The gas at #9 and #10 cross-overs was also sampled for oxides of nitrogen using the A.S.T.M. D-1607-60 method. No oxides of nitrogen could be detected using this method of analysis and the laboratory sampling techniques.

COKE OVEN GAS VOLUME

The decrease in emissions is expected to result in an increase in the average volume of coke oven gas. Measurements made in the standpipes during charging (Appendix G) indicate approximately 1135 CFM additional gas was drawn with high pressure steam ejection,

Table 8. COKE OVEN GAS ANALYSIS

Measured Parameter	Date					
	1970 Avg.	1972[a] 8/25-9/1	1972 10/17-10/28	1973 1/1-1/15	1973 5/14-5/31	1973 Dec.
CO_2 (% vol.)[b]	2.9	2.5	2.3	2.2	2.4	3.0
Illuminants[c] (% vol.)	3.0	3.0	3.0	2.9	3.0	2.8
O_2 (% vol.)	1.3	1.5	1.3	1.2	1.3	1.3
CO (% vol.)	6.6	6.3	6.2	6.3	6.3	6.4
H_2 (% vol.)	49.2	49.9	49.9	49.8	49.8	49.5
CH_4 (% vol.)	32.4	31.1	30.3	30.5	29.9	29.6
N_2 (% vol.)	4.9	5.8	7.0	7.0	7.3	7.4
BTU (Gross)	551	542	535	535	531	524
BTU (Net)	501	492	486	485	482	475
Spec. gravity	0.41	0.41	0.41	0.41	0.41	0.42
H_2S in gas (grains/100 ft^3)	300	322	328	195	280	--
HCN in gas (grains/100 ft^3)	54	193	42	50	32	--

a. Sampling performed just prior to start of new system
b. Includes any acidic gases such as H_2S, HCN, etc.
c. Any constituents that will react with fuming sulfuric acid; mostly unsaturated hydrocarbons such as ethylene-C_2H_4

Table 9. GUM CONTENT OF CIRCULATING WASH OIL

Measured Parameter	Date 1972 8/24	 1972 10/27	 1973 1/12	 1973 5/18	 1973 6/1	 1973 Dec.
Insoluble gums (g/l.)	0.34	0.14	0.28	0.31	0.25	0.18
Soluble gums (g/l.)	0.12	0.18	0.31	0.13	0.14	0.18
Total gums (g/l.)	0.46	0.32	0.59	0.44	0.39	0.36

when compared to the original low pressure steam. Extropolating those results for the present header pressure of 130-140 psi, indicates an approximate increase of 50% or about 570 CFM additional gas. Assuming an average steam aspirating time of 4.5 minutes, and five charges per hour, approximately 12,800 ft^3 additional coke oven gas is produced per hour. Approximately 800,000 ft^3/hr. of coke oven gas is produced at P-4 battery. This represents a calculated increase of 1.6% The addition of jumper pipes to this battery could result in an additional 75% increase or about 9,600 ft^3. The overall increase in coke oven gas of about 22,400 ft^3 represents a 2.8% increase with jumper pipes over the original production. This increase represents the emissions that formerly went into the atmosphere as well as an increase in the quantity of air drawn into the system.

The importance in minimizing the time span during which steam aspiration is used, can be related to the operation of the primary cooler. During the summer an excessive increase in gas will overload the primary cooler causing an increase in the gas temperature. If the limits of the gas exhauster are reached, the increased back pressure will reduce oven suction.

The recording charts for coke oven gas show significantly higher peaks than previously. These peaks are attributed to excessive use of steam on ovens not being charged. These charts also indicate that approximately 100,000 ft^3/hr. more coke oven gas is now produced from the five batteries, over that produced 18 months earlier.

SECTION VIII

PROJECT RESULTS - EQUIPMENT PERFORMANCE

GRAVITY FEED LARRY CAR

As part of previous development work, a full scale gravity feed hopper had been built and tested at the Swissvale yard of Koppers Company (Figure 33). The purpose of that test was to ensure that the basic concepts of the feed system could be realized prior to building the new larry car. Some of the conclusions in the test report indicated that:

1. The hopper and butterfly valve can control the flow of all type coals to maintain a coal seal in the hopper at all times.
2. The system provides for nominal misalignment problems.
3. The hopper can satisfactorily discharge coals having a wide range of moistures (4-9% on final test)
4. The system provides a uniform coal flow rate during the entire emptying interval.

The experience to date indicates that these conditions were only partially achieved in full production operations.

Maintain Coal Seal

The flow of coal from the hopper and drop sleeve is such that a coal seal is maintained continually. At the end of charging, as sensed by a bottom coal level detector, the butterfly valve is closed so that a 15" layer of coal seals the charging hole.

Drop Sleeve Misalignment

The design of the drop sleevewas such that with an initial misalignment of 1 1/2", the sleeve was to seat within the charging hole ring.

In order to satisfy the alignment tolerance conditions, the charging hole rings were realigned by freeing them from the

GRAVITY FEED HOPPER
TEST ARRANGEMENT

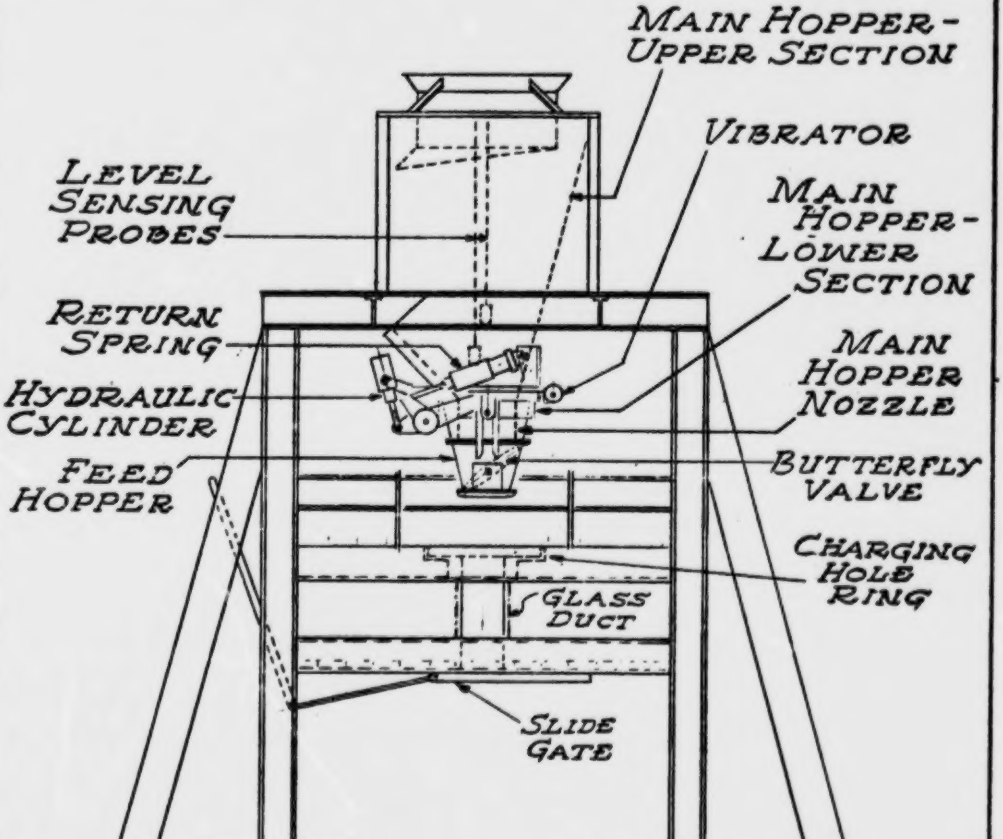

MAIN HOPPER - UPPER SECTION
VIBRATOR
LEVEL SENSING PROBES
MAIN HOPPER - LOWER SECTION
RETURN SPRING
MAIN HOPPER NOZZLE
HYDRAULIC CYLINDER
FEED HOPPER
BUTTERFLY VALVE
CHARGING HOLE RING
GLASS DUCT
SLIDE GATE

Figure 33

permanent brick and re-positioning so they were concentrically aligned with the drop sleeves. The surface in the immediate vicinity of the rings was leveled so as not to interfere with the housings for the butterfly proximity limits and the hydraulic driven rotary actuator.

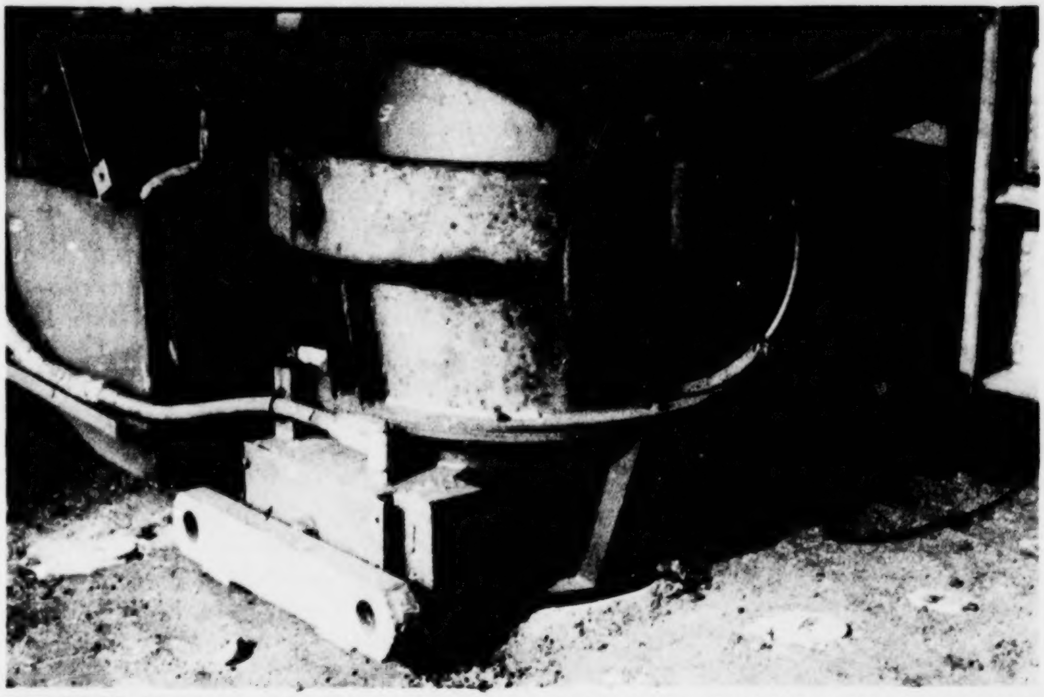
The alignment of #3 charging hole rings could not be optimized in many instances because to do so would result in a constriction of the charging hole under the ring and would result in exposure of part of ring to the oven gases. The net result is that many of these rings are slightly displaced to the coke side with respect to the drop sleeve by approximately 1/2" to 1".

The original seating performance was unsatisfactory. The rotary actuator housing or limit housing would strike the battery surface because of a swing motion of the drop sleeve. This would prevent the drop sleeve spherical surface from properly seating in the charging hole ring. A new spherical ring was made with a 1/2" extension. This permitted the drop sleeve to seat without interference from the housings (Figure 34).

The drop sleeves used to swing as they were lowered. This was caused principally by the drop sleeves not being balanced and the downward motion tends to be in an arc that is restrained by vertical guides. Also the connecting link between the lowering arms and the drop sleeve pin was solid. If the drop sleeve seat made contact against the charging hole ring in such a manner that it was tilted, it could be driven against the ring. Instead of permitting the sleeve to slide in, it would jam it against the side of the ring. Three modifications were made to correct the problem. The drop sleeves were counter-balanced with weights. A slotted link replaced the solid link. A guide was also furnished to force the drop sleeve to be directed downward without significant oscillation. These modifications for the most part corrected the seating problem.

The pins and links which are part of this system must be maintained free with frequent lubrication, to allow proper seating.

DROP SLEEVE SEATING



THE DROP SLEEVE SEATED IN CHARGING HOLE RING WITH EXTENDED SPHERICAL SEATING RING. NOTICE A COUNTERWEIGHT BOLTED TO FRONT OF BUTTERFLY LIMIT HOUSING. THIS WEIGHT HAS SINCE BEEN REMOVED. A SOLID LINK CAN BE SEEN BETWEEN THE LOWERING ARMS AND THE DROP SLEEVE PIN. THIS WAS CHANGED TO A SLOTTED LINK.

FIGURE 34

Drop Sleeve Misalignment (continued)

At the present time #1 and #2 drop sleeves seat consistently in the charging hole rings. There are still occasional problems with #3 drop sleeve seating. This problem exists because the charging hole rings on some ovens cannot be moved sufficiently to provide optimum alignment with the drop sleeve. The seating problem could be improved by moving #3 hopper (coke side) to provide a better average position. This would be a major job.

For a new installation where hopper and drop sleeve alignment are optimized, this system can provide for a limit of about 1 1/2" misalignment, and still consistently seat properly.

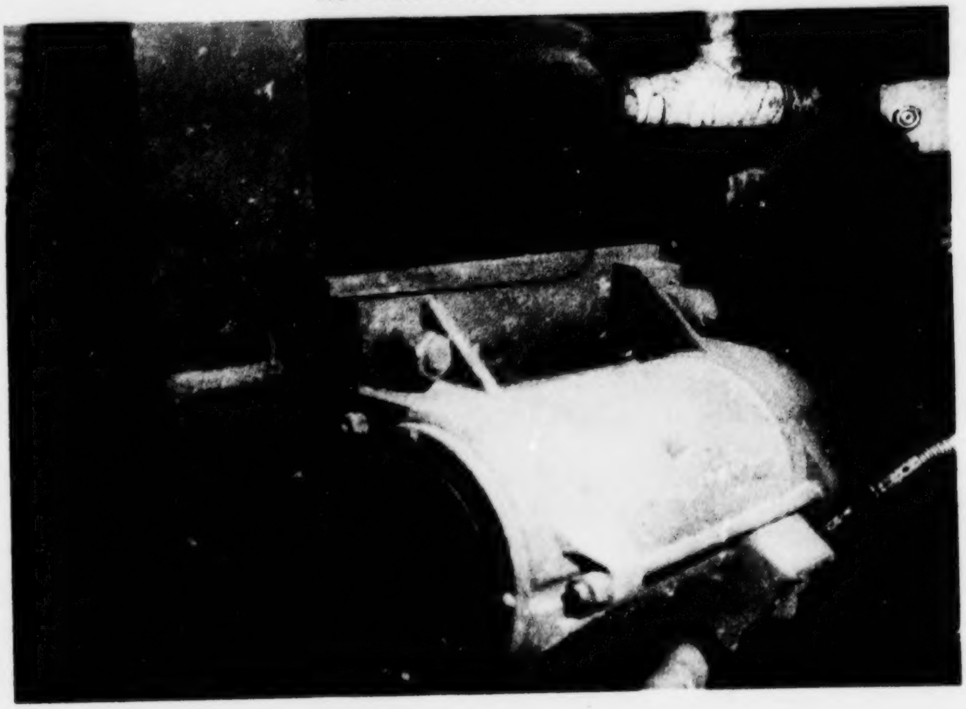
High Moisture Coal

The hopper can discharge coals over a wide range of moistures, but the use of a vibrator is usually required. The discharge of the coal through the drop sleeve is more difficult, and the presence of the vibrator on the hopper is not sufficient to cause flow under all conditions.

The use of vibrators, as originally installed, was a source of problems since the car started operations. The mechanical vibration has caused many parts to fail because the fasteners were loosened or sheared. All such fasteners had to be welded to prevent losing them. During the interim period the sleeves were dropped several times. A drop sleeve return spring fractured as a result of fatigue stresses. The vibrators themselves failed and it is believed that the failure mechanism was initially mechanical wear in the bearing housing. It caused the top level sensors to loosen and drop the paddle wheel. There were a few times when it caused the hopper position proximity switch contacts to vibrate if the drop sleeve was not fully down and the limit was just on the verge of operating. This would cause the butterfly valve to close for unexplained reasons.

The worst symptom of this problem was discovered in July 1973 when fatigue cracks were found in the hopper body at the toe of a circumferential fillet weld joining the type 304 stainless steel hopper body to a carbon steel bottom flange. This failure occurred on all three hoppers. Figure 35 shows the original

HOPPER FATIGUE CRACK



NOTICE FATIGUE CRACK WHERE THE HOPPER BODY IS JOINED TO A BOTTOM STEEL FLANGE. THE VIBRATOR IS SEEN IN THE ORIGINAL MOUNTING LOCATION. THE BOTTOM COAL LEVEL SENSOR CAN BE SEEN ABOVE. THIS HAS BEEN REPLACED BY A COUNTERWEIGHTED ROD TYPE SENSOR.

FIGURE 35

High Moisture Coal (continued)

vibrator mounting position and an example of a fatigue crack.

It was suggested that the vibrators be relocated on the conical portion of the hoppers. A solid base was prepared for the vibrator which mounted on a long channel to distribute the vibration over a wide area.

Since this change, there has been improved life with the vibrators, and no evidence at this time of any mechanical failures attributed to vibration. However more observation time is required to make a definitive conclusion.

Because of the drop sleeve design the coal feed is not reliable when the coal moisture is approximately 8% or more. With this moisture content the operator must frequently use a steel rod to poke the hole from the top of the drop sleeve in order to initiate coal flow. Once the coal flow starts it will usually continue to pour. The emission data shown for charges made with 8.3% coal moisture in January, 1974 indicate that the operator had to use a bar on at least one drop sleeve for six out of ten charges.

The operator will try to get out of this troublesome problem by oscillating the butterfly valves until the coal has been completely discharged from the drop sleeves. A 10-15" coal seal will result in some packing of coal when the drop sleeve is raised after a charge. This small amount of packing causes no apparent problem except with coal having a high moisture content.

The incidence of stalled butterflies during leveling is greatly increased during wet coal conditions as described previously in Section VI (Page 76).

Uniform Coal Flow

Consistent coal flow from all three hoppers would permit the adjustment of coal feed rates to minimize the leveling time. This feature was never achieved consistently. The time charts included with emission data (Appendix D) for December 1973 and January 1974 clearly indicate the variable feed rates.

Uniform Coal Flow (continued)

Some of the problems affecting coal feed were discussed in the previous paragraph on high moisture coal. In addition two frequent problems at the start of the project that resulted in coal packing were:

1. Too much coal left from the previous charge.

2. Drop sleeves have to be raised for some reason after they have been lowered, but prior to charging.

Even with normal 7% moisture the coal would frequently pack after raising the drop sleeve, if the coal seal was more than 15". This condition seldom occurs since the installation of a bottom level sensor that maintains a consistent 15" coal seal. The second problem occurs infrequently since the performance of drop sleeves in seating within the charging hole rings has improved.

Except for a few isolated cases, once the coal flow has been initially started, it will continue, though not necessarily at a constant feed rate.

Improvement of Coal Flow Problem

At times with conditions of high moisture, the final coal seal appears to be concave, indicating a tendency for coal to pack around the sides of the drop sleeve. The tapered insert between the drop sleeve shell and the butterfly cylinder is believed to be a major contributing factor. The packing of coal at the insert may cause the formation of a bridge above the butterfly.

Several steps were taken to reduce the problem. A coal poker was installed in #3 hopper. The coal poker was hydraulically driven in a vertical cyclic motion with its lowest point about 2" above the butterfly valve. The performance of this device was marginal. It would usually work when coal packed in the drop sleeve because previously the drop sleeve had been raised with more than a 15" layer of coal remaining above the butterfly valve. However with very wet coal (8% moisture), it would frequently fail to break the bridge.

Improvement of Coal Flow Problem (continued)

If the coal flow stopped because coal backed up in the charging hole, the use of the coal poker tended to pack the coal and make the condition worse. The coal poker was removed and a hydraulic vibrator was mounted directly to the side of #3 drop sleeve to see if this would improve the coal feed without damaging the charging hole rings. The vibration force was adjustable by the setting of a hydraulic flow control valve. This device could be adjusted so that it would always start coal flow, but the vibrating force required was of a magnitude that would apparently result in eventual loosening of the charging hole rings. The environment of fire and vibration made it vulnerable to hydraulic hose leaks. It has since been removed.

A preferred solution is to re-design the hopper drop sleeve so that the initiation of coal flow requires no auxiliary devices. The present drop sleeve insert has a 57^{o} slope. Work has been initiated into ways of achieving a minimum 67^{o} bin angle, based on criteria which resulted from hopper design research by U.S. Steel.

Minimize Stalling of Butterfly Valve

When the coal backs up in the charging hole ring, the butterfly oscillation tends to pack the coal and eventually stalls the butterfly. The operator has been trained to watch the oscillate lights. If they stop cycling ON and OFF, the operator resets the sequence alarm and waits 10-15 seconds. This gives the leveler bar time to remove enough coal to open the charging hole. The operator can then start up the butterfly to complete the charge. This procedure appears to be effective at least 98% of the time.

An improved procedure would utilize coal flow meters to monitor the performance. As soon as coal flow stopped as a result of coal backing up the charging hole, the butterfly oscillation could be terminated before it packs the coal.

A hydraulic pressure gage was connected to the butterfly oscillate hydraulic line. The hydraulic pressure with no coal, or with regular feeding of coal is the same. Consequently the operator cannot use this gage to determine when coal is not flowing because it is packed above the butterfly valve. When coal

Minimize Stalling of Butterfly Valve (continued)

backs up from within a charging hole, the pressure goes up when the butterfly stalls, and this is easily seen on a gage. It does not indicate when coal flow stops, but rather when the butterfly valve stalls. The butterfly valve oscillate lights already provide this information, consequently the pressure gage is of no use as a coal flow indicator.

Conclusions - Coal Feed System

The present coal feed system has sufficient provision for normal misalignment with charging holes, and is able to maintain an adequate coal seal at all times.

The system does not properly discharge coal with 8% moisture and must be redesigned to achieve this necessary goal. The system does not provide a uniform coal feed during charging, but with the addition of jumper pipes, this feature is not required. The control of the coal feed is necessary to ensure that leveling is required at only one charging hole. The use of coal level detectors can accomplish the requirements, if the coal feed system can reliably charge coal with 8-10% moisture.

There are several desirable features which should be provided on a coal feed system to optimize charging performance and car reliability.

1. The coal feed system must reliably discharge coal under all normal operating conditions (various amounts of moisture, etc.).
2. A sensor that can provide the operator with coal flow information from each hopper is desirable.

Hopper Volumetric Measuring Sleeves

The gravity feed hoppers have been provided with adjustable measuring sleeves. These sleeves are very difficult to adjust and have a tendency to come apart. A safety chain has been added to hold the bottom section of the measuring sleeve so that it cannot fall into the hopper. The measuring sleeve sections were not balanced and tended to jam together.

Hopper Volumetric Measuring Sleeves (continued)

The measuring sleeves have been re-designed to alleviate these problems. The modified design has not yet been installed.

Reliability Problems with Hopper Components

The inability to be able to maintain negative oven pressure during leveling results in emissions during part of this operation. This also affects the reliability of the car. Internal oven pressure causes flame to be directed out of the charging hole between the charging hole ring and the drop sleeve, resulting in damage to electrical sensors and hydraulic hoses. This is particularly evident when the drop sleeve does not seat properly in the charging hole ring, leaving an open gap (almost restricted to #3 charging hole).

The latest arrangement of hydraulic hoses and the latest arrangement of proximity switches have reduced the possibility of failure because of flame from the charging holes.

The original limit switches that monitored the hopper position (UP, DOWN, CLEAR) were hatchway type limits. These had a very short life since any heat from flame would cause them to fail in spite of the protective shielding. The HOPPER CLEAR limit is set to be actuated when the drop sleeve raises sufficiently to clear the charging hole rings. This permits the car to travel by means of operating the EMERGENCY TRAVEL PB. These limits were replaced by proximity switches rated 450° F, and more elaborate heat shielding was added. The performance of these limits has been reliable since that time.

The original switches for the butterfly valve motion (CLOSED, OPEN, CCW) were and still are the proximity type switch. The switches are housed in a steel box which provides good protection but is located very close to the charging hole ring and the resulting source of flame. The life of these switches has been good at #1 and #2 butterfly valve. The life of those at #3 butterfly has been considerably less because of the much more frequent occurrence of flames from between the charging hole ring and the drop sleeve. There have been three butterfly limits fail in 4 1/2 months, all at #3.

Reliability Problems with Hopper Components (continued)

At the present time a high temperature material rated 1800° F is wrapped around the switches in order to prolong their life (# 3 hopper).

The wiring for these sensors has held up reasonably well. It is rated for 1000° F temperature and is enclosed in conduits or armored cable.

The maintenance of the butterfly valve hydraulic hoses has been a problem. The original hoses had an extremely short life. Several different hoses were tried. The best results were obtained with a heat-resistant hose having a double layer of woven asbestos insulation under the armor. The original hose was an expensive 7 foot long piece that required removing the rotatory actuator housing cover to change, a maintenance job that normally took about 90 minutes. The arrangement was changed so that a 3 foot hose was required that takes about 20 minutes to change.

The butterfly valve is powered by a rotary actuator. Two of these have failed during 16 months of operation. The mechanical failures were apparently associated with slight movement of the actuator housing during operation. The mounting design makes it difficult to anchor the housing in a manner that prevents any movement.

Hopper Coal Level Control

At the beginning of the AISI program several coal level sensors were tested on an existing Wilputte larry car used on P-4 battery. These include a SONAR type device, capacitance probe, pressure sensitive device, vibrating rod, and a paddle wheel drive device. The results of this test work indicated that the paddle wheel drive device was more reliable then the other tested units. This particular unit was a "Bin-O-Matic". The second and third level sensor were applied with a baffle above the paddle to protect the unit when the hopper was being loaded at the coal bin.

After a year's use in production operation, the Bin-O-Matic is still in use at the 80% level. There have been only one or two units changed in this position since the car was installed. The units were changed because of an internal gear failure.

Hopper Coal Level Control (continued)

The units are located in an area where reliable operation has been obtained and they are considered successful.

The bottom level sensor did not prove adequate because it was not located in a proper position to sense the coal level in the drop sleeve at which time the butterfly is closed. In order to maintain a proper coal seal of 15", it is necessary to close the butterfly when the coal level just drops below the bottom of the hopper cylinder. The Bin-O-Matic was located in the tapered part of the hopper, about 30" above the bottom of the cylinder. It was mounted at this location, since there was no mounting space available below that point. An electric operated timer was energized when the Bin-O-Matic was activated (no coal). After a pre-set timed period, the butterfly would close. With a uniform coal flow this system would work. However the coal flow is quite variable in the final feed,and it was impossible to maintain a proper coal seal.

There were other problems associated with this bottom level sensor. Being at the tapered portion of the hopper, the coal flow was not as regular. The coal was more apt to pack on the baffle creating an occasional void. There was almost always a void that occurred just after the drop sleeve was lowered. This would cause the sensor to indicate "EMPTY" for about 5-10 seconds. This problem was eliminated by interlocking the circuit of the bottom level sensor so that the logic was available only after the 75% level sensor was activated.

The shaft of the Bin-O-Matic was more susceptible to coal packing, apparently because of its location in the hopper. It then is necessary for some one to climb inside the hopper and remove the coal from the shaft. This might occur on the average of once a month.

An attempt was made to use a Bin-O-Matic in the drop sleeve. This was not successful since coal would pack around the shaft causing it to stall, thus indicating the presence of coal. J&L then specified an arrangement for a bottom coal level sensor consisting of a counterweighted rod which extends into the hopper where the original paddle wheel sensor was located. This

Hopper Coal Level Control (continued)

arrangement is shown on Figure 36. The absence of coal causes the counterweight to rotate the rod away from the hopper wall and operate a proximity switch. The presence of coal pushes the rod to the cylinder wall, overcoming the counterweight. This device has consistently maintained a coal seal in the drop sleeve and has not yet required any maintenance.

The Bin-O-Matic used at the top of the hopper was subject to failure from the hopper vibration. Also the top coal level would drop frequently when travelling to an oven. The operator could not consistently use this indicator to determine initial coal flow. The counterweighted rod was installed at the top of the hopper and has been working successfully in this location.

On a new car the counterweighted rod type level sensor would be recommended for all locations. The length and position of the rod can easily be adjusted to be in the proper position to sense coal flow and the coal level. Its moving part consisting of a pivot pin is located outside the hopper away from the coal. The proximity switch sensor is also located away from the coal outside the hopper.

AUTOMATIC LID LIFTERS

The lid lifters, as originally installed, were a source of excessive maintenance which resulted from two general problems:

1. The close clearances between the magnet and the drop sleeves, and also the bottom of the magnet and a lid on the battery resulted in frequent mechanical failures.
2. The environment (Primarily flame) caused failures in electrical sensors and wiring, as well as hydraulic hoses.

Close Clearances

The problem of close clearances is unique with this installation. The drop sleeve spherical seating ring had to be lowered 1/2" in the field to permit the drop sleeves to seat, thus reducing the 2 1/4" design clearance, which never existed. In addition

COAL LEVEL SENSOR

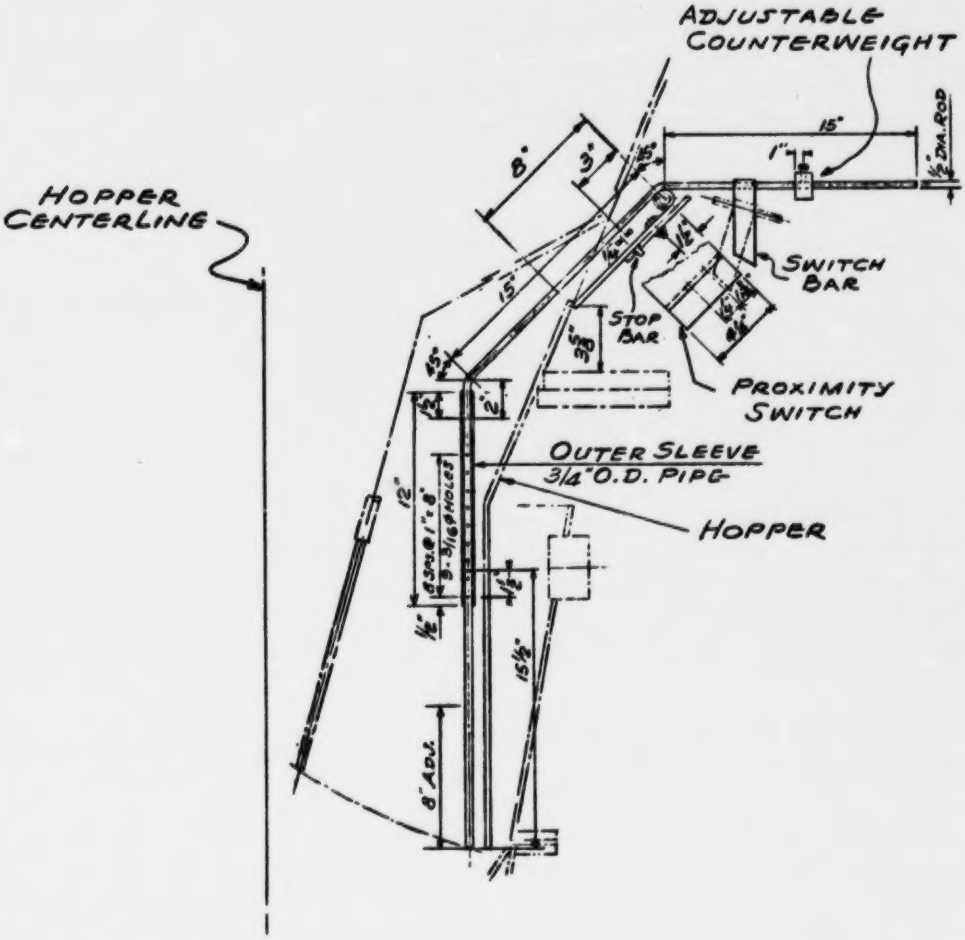

ADJUSTABLE COUNTERWEIGHT
15"
1"
1/2" DIA. ROD
8"
3"
45°
15"
1/2"
SWITCH BAR
STOP BAR
3 5/8"
PROXIMITY SWITCH
HOPPER CENTERLINE
45°
2"
1 1/2"
OUTER SLEEVE
3/4" O.D. PIPE
12"
8 SPS. @ 1" = 8"
9-3/16 Ø HOLES
HOPPER
1 1/2"
1/2"
15 1/2"
8" ADJ.

Figure 36

Close Clearances (continued)

the drop sleeves do not always raise the full amount because of the remaining coal load and friction. If the drop sleeve raised within 3/4" of the top, the hopper UP limit was supposed to indicate it in the UP position. The clearance is further reduced by the fact that the conduit connection for the magnet wire and the contact lid limit can be seen to be higher than the reference clearance point. Thus with normal conditions the clearance can be less than 3/4". In addition to this, at times the magnet assembly was tilted causing the clearance to be decreased. Also the drop sleeve is not always horizontal in the UP position due primarily to an unbalanced remaining coal load, particularly when excessive coal remained.

The clearance between the bottom of the lid lifter magnet and the top of the lid resting on the battery was even tighter. The approximate design clearance of about 4 1/2" did not exist. This clearance was based on a 1" flat pancake type lid. The type of lid used on this battery was originally 2 1/2" with lugs. One quarter inch was later removed from the lugs reducing the heighth to 2 1/4". The lid lifter did not always remain at the elevation shown on the drawing. Since a mechanical spring arrangement is provided to raise the lid lifter in case of an electrical or hydraulic failure, a double-solenoid three-position hydraulic valve is used. Because of internal leakage, the lid lifter did not remain in the extreme UP position thus decreasing further the clearances.

On a 20 year old battery the surface is not uniform, thus considerably reducing the apparent clearances.

These close clearances at times resulted in interference between the drop sleeve and the lid lifter. The principal problem here was damage to the conduit boxes on the magnet and bent guide arms on the lid lifter mechanism.

The close clearance between the lid lifter magnet and the lids on battery caused the lids to be struck and moved out of position. When the time came to replace the lids they would not seat properly.

Close Clearances (continued)

The following changes were made to minimize interference problems:

1. The hydraulic pressure was increased to 1300 psi to provide more force to raise the drop sleeves.

2. The lever operated limit switch for HOPPER UP sensing was subject to frequent failures causing the hopper to get an UP indication when it was not sufficiently UP to have adequate clearance. This was replaced by a more reliable proximity switch rated 450° F.

3. The conduit boxes were revised so that the profile was decreased 1/4" to 1/2".

4. The lid lifter guide arms were re-designed, with heavier steel so they would not bend so easily.

5. A wear bar is located between the lid lifter traverse wheels and the filler plate. The last 18" of wear bar was removed to permit the lid lifter to lower 3/4" when it extends. The remaining wear bar was tapered near the end to provide a bumpless extend motion.

6. The electrical circuit was revised to energize the UP solenoid at all times, so as to maintain the lid lifter in the full UP position to provide maximum lid clearance.

There were two other causes of interferences. With the hydraulic pump shut off the two-position double solenoid valves can be momentarily electrically energized or manually actuated. The equipment does not move because there is no hydraulic pressure. When the pump is later turned on, the hydraulic power will cause equipment to move in accordance with the present solenoid position. Thus it is possible to have a drop sleeve lower and the lid lifter extend simultaneously when the car is placed in service after an extended outage. This is known to have happened causing the guide arm to bend.

This was corrected by initiating an EMERGENCY TRAVEL operation on all parts of the car whenever the hydraulic pump start

Close Clearances (continued)

push button is operated, thus causing all equipment to move to the TRAVEL position.

The other interference problem was caused by excessive amounts of coal in the battery where the lids were placed. This would elevate the lids. It is believed that instances have occurred, when the lid was raised and tilted because of coal, that resulted in jamming the lid between the mechanism and the battery top when the car passed over, causing a failure sometimes manifest by a broken hydraulic cylinder rod. This situation has been corrected by alerting the operating people to this situation.

Presently, this once serious interference problem is no longer a significant factor, and the over all car reliability is much improved as a result.

Fire Damage

During charging, if the gas passage way in the oven does not remain open, internal pressure causes burning gas to blow out of the oven between the drop sleeve and the charging hole ring. Since the opening is usually very small it errupts with a blow torch effect. Although the lid lifter components are for the most part about six feet from the center of the charging hole, they are occasionally subject to the heat of burning gases.

On a more frequent basis, they are subject to heat damage when lids are being removed from the oven that was just pushed (two ovens south of the one just charged). The heart of the lid lifter parts are then located directly over the oven that was just charged. If internal pressure exists in the oven, flames will be blowing out of the charging hole between the circumference of the lid and the charging hole ring. This is very hard on sensors and hydraulic hoses.

The lever operated limit switches cannot stand up under this abuse. The contact blocks are destroyed and the mechanical return springs are stress relieved. In addition the wet

Fire Damage (continued)

environment caused by the presence of a quench tower results in mechanical binding of the lever arm.

There are six limit switch sensors on each lid lifter. EXTEND and RETRACT limits monitor the horizontal motion, an UP limit monitors vertical travel, clockwise and counterclockwise limits sequence the oscillate motion, and a pin operated limit indicates that the magnet has a lid. The first five sensors were replaced at #3 lid lifter with proximity switches rated for 450° F service. These limits have greatly improved reliability. They are still subject to temperatures which significantly exceed the 450° F for a short time. These switches are covered with a high temperature insulation (Refrasil) to protect against fire.

The lever operated limit which indicates that a lid is in contact with the magnet is still the original switch, simply because it is difficult to use a proximity switch for this application. This switch is used only for an operator's indicating light, and its failure will not interfere with the control sequence.

This switch is also well removed from the oven that was just charged during a REMOVE LID operation on the oven that was just pushed. Consequently its exposure to heat is less than the other sensors. There were two limit switch failures in a year at this location. About once every 4-6 months the steel rod which protrudes from the magnet must be removed and dirt cleaned out to prevent it from sticking.

The clockwise and counterclockwise limits failed more than any other sensor on the lid lifters (lever operated switch). When these fail the lids will not be oscillated when replaced, but this will not stop the control cycle which allows so much time to oscillate. Consequently their failure does not significantly affect the reliability since they do not stop the process and can be repaired or replaced when maintenance people are available. Failure to oscillate the lids will usually result in a poorer oven seal.

Fire Damage (continued)

To improve the electrical reliability of the lid lifter operation, all wiring and conduit work was re-routed in such a manner as to minimize exposure to flame and abrasive wear during operation of the lid lifters. One thousand degree wiring is used on all parts of the lid lifter.

There are two other sensors associated with the lid lifters. A current sensing device determines when the magnet is energized or de-energized. This is located in the control room as part of the magnet control and has not experienced any malfunction to date.

The lid lifter DOWN sensor is a hydraulic pressure switch located in the hydraulic control cabinet. This sensor has on occasion required a screwdriver adjustment to make it sense when the magnet is lowered, but has had no failures requiring a replacement. The adjustment is usually required, if at all, when there is a significant change in the temperature of the ambient air. An adjustment was required an average of two to three times a year.

The hydraulic hoses which operate the two cylinders are also subject to failure from exposure to burning gases. These hoses were replaced with a G-SM Goodall hose which significantly improved the life.

The steps taken to minimize failures from damage occurring as a result of exposure to high temperatures have significantly improved the over-all reliability. There have been more failures with #3 lid lifter because it is exposed more frequently to the burning gases. Since September, 1973 there were three known failures with #3 lid lifter caused by limit failures as a result of flame. It is believed that the heat shielding will improve this performance.

Magnets

There have been three magnet failures since the car was placed in operation. Two were caused by lead wire exposure to heat and the third was caused by the drop sleeve lowering into

Magnets (continued)

the magnet when the hydraulic pump was turned on (this problem has since been corrected). This appears to be a satisfactory life span (neglecting the third failure). Part of this success is attributed to the fact that the magnet only holds the lid while it is being removed or replaced. Thus the lid temperature is not a significant factor in magnet heating.

Hydraulic Panels

The arrangement of hydraulic panels for each lid lifter and drop sleeve has permitted the operating people to get out of trouble in times of failure, and has permitted maintenance adjustments to be made more easily.

Improved Design

Most of the maintenance problems experienced with these lid lifters could be avoided on a new design. Adequate clearances could be assured in the design. The exposure of the lid lifter to high temperature would be minimal by locating the lid lifter in the opposite direction so that when removing lids from the oven just pushed, the lid lifter is not directly above the oven just charged.

Careful selection and location of sensors and hydraulic hoses will improve reliability. The oscillate limits are not required, since this function can be performed hydraulically. It is believed that the present sensors (other than OSCILLATE), properly applied and shielded will provide reliable service for a re-located lid lifter, and will provide adequate service on the present lid lifter location.

DAMPER, STEAM VALVE, AND STANDPIPE CAP OPERATING LINKAGES

There have been many problems with these linkage systems and their performance has not been reliable. With the present operation, the larryman will always leave the cab to check the operation. If it was not properly executed, the lidman completes the operation.

DAMPER, STEAM VALVE, AND STANDPIPE CAP OPERATING LINKAGES (continued)

The major problems exist because on an old battery (20 years) the standpipes lean in all directions and uniform dimensional properties on each oven cannot be maintained. The actuator and linkage design did not incorporate sufficient flexibility to account for this. It was necessary to increase the length of the cross piece on the end of the car operated rotary levers so that the operating band was increased from 1 1/2" to 6". A guide plate was placed around the steam valve actuator magnet attached to lever #2 so that the actuator shoe plate would be properly held when the magnet was not right on center. The magnet power was increased by a factor of four to maintain sufficient power to operate the linkage when not perfectly aligned. Further the linkages at each standpipe had to be bent to try to align for each particular set of dimensional misalignment. In many cases extensions had to be welded to the existing levers. #1 lever arm had to be extended 9".

Steam Linkage System

In addition to the general misalignment problems, the following problems were experienced with the steam linkage system.

1. Steam linkage rods between the shoe plate and the lever bend or break (Figure 38).

2. The shoe plate binds to the pin and does not rotate freely.

3. The linkage had to be counterbalanced to permit the steam to remain ON if lever #2 is lowered without energizing the electromagnet. This operation is frequently required, and can be performed with the EMERGENCY TRAVEL PB.

4. The linkage did not have sufficient means to adjust the steam valve so that it would turn fully ON and fully OFF each time. Frequently the necessary adjustment prevented the valve from being fully turned ON.

5. Steam linkage levers had to be bent to provide adequate operation as a result of a leaning standpipe.

BENT STEAM LINKAGE ROD

FIGURE 37

Steam Linkage System (continued)

6. On some ovens interferences exist between the steam valve linkages and the lid operating linkages which is particularly noticeable when the oven is dampered OFF. Figure 38 shows good clearance between the lid operating mechanism and the steam linkage. Figure 39 shows a very tight clearance.

A new steam valve operating linkage has been designed to eliminate those problems. It has not yet been installed.

Standpipe Cap Operating Mechanism

The standpipe cap operating mechanism did not perform reliably. The following problems were experienced.

1. The original design had a lid rotate shaft supported by a pillow block at one end and the gooseneck lugs at the other side. The pillow block was not designed for misalignment and was not particularly suited for high temperature operation. The shaft would bind in this pillow block preventing proper operation of the cap. These pillow blocks were replaced with self-lubricating, high temperature, self-aligning bearings rated for 1000° F service. While this solved most of the problems, some additional shafts started sticking because they were larger than the maximum allowed tolerance. New shafts were made to replace the oversized ones.

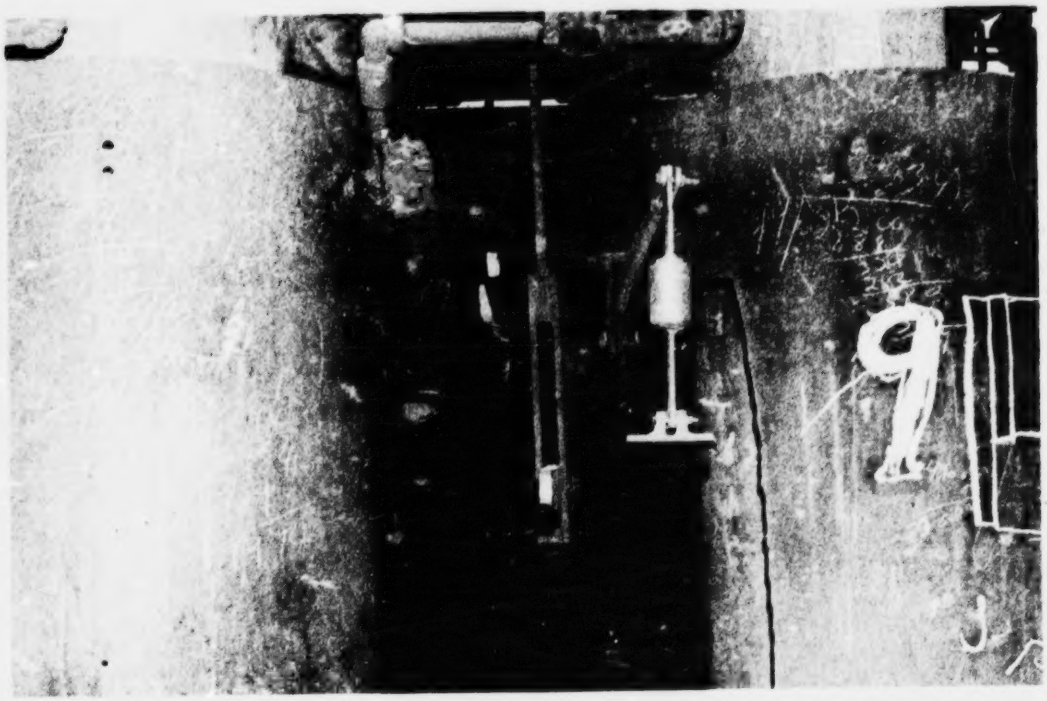
2. The shaft lugs on gooseneck frequently broke because of the stresses that occurred when the cap reached the open limit. Cap stops had to be added (refer to Figure 40 which shows hinge lugs that broke and were repaired).

Since making these modifications the operation of the standpipe cap linkage has fairly good reliability, except for cases where there are interferences with the steam valve linkages.

Damper Valve Operating Mechanism

The damper valve operating mechanism did not perform reliably. Aside from alignment troubles, there are two major problems:

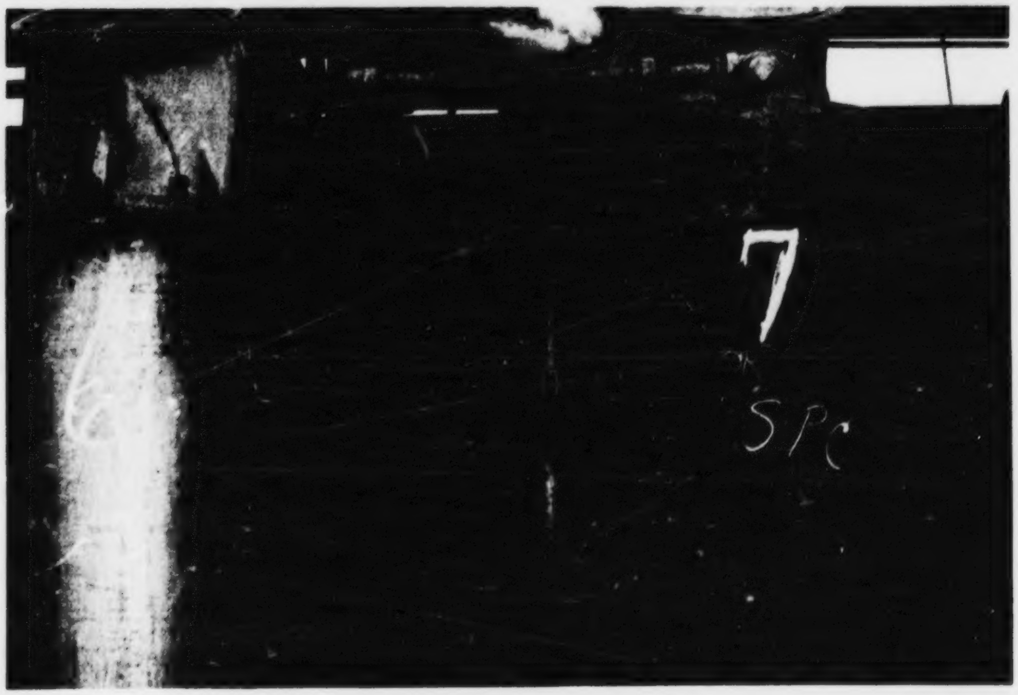
ASCENSION PIPE OPERATING LINKAGE



GOOD CLEARANCE BETWEEN THE LID OPERATING MECHANISM AND THE STEAM LINKAGE.

FIGURE 38

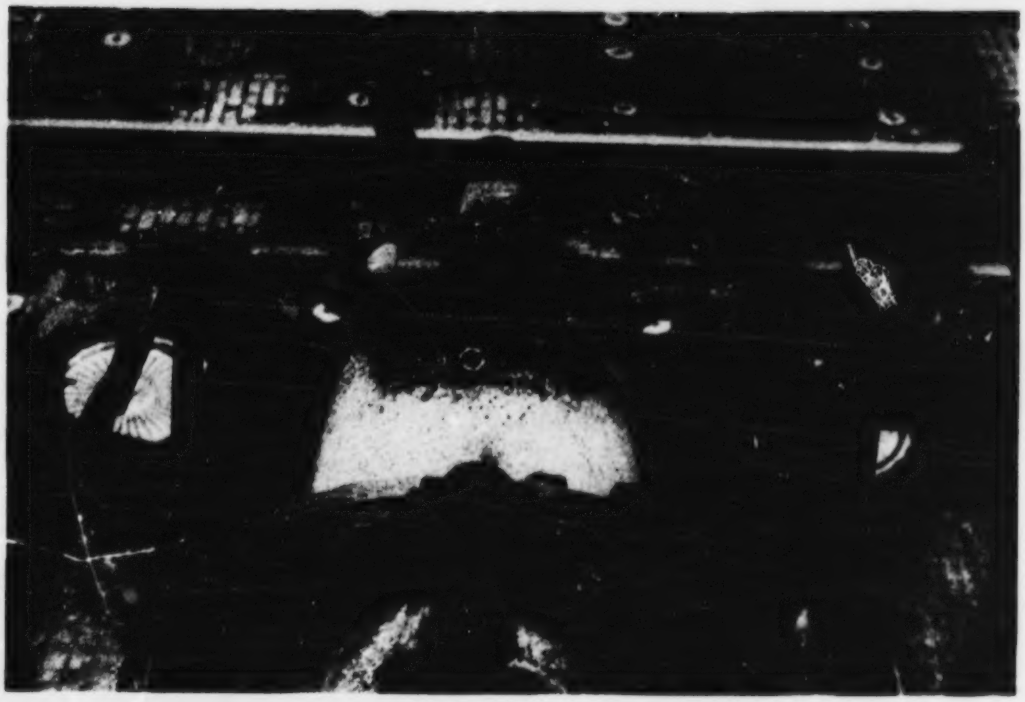
ASCENSION PIPE OPERATING LINKAGE



TIGHT CLEARANCE BETWEEN LID OPERATING MECHANISM AND THE STEAM LINKAGE.

FIGURE 39

STAND PIPE CAP HINGE LUGS



BROKEN CAP HINGE LUGS THAT HAVE BEEN RE-WELDED. A NUT HAS BEEN WELDED IN PLACE TO PROVIDE A STOP THAT WILL PREVENT HINGES FROM BREAKING.

FIGURE 40

Damper Valve Operating Mechanism (continued)

1. The Pullman damper shafts bend, apparently as a result of the impact after the mechanism falls free when the counterweight rotates past the neutral point.

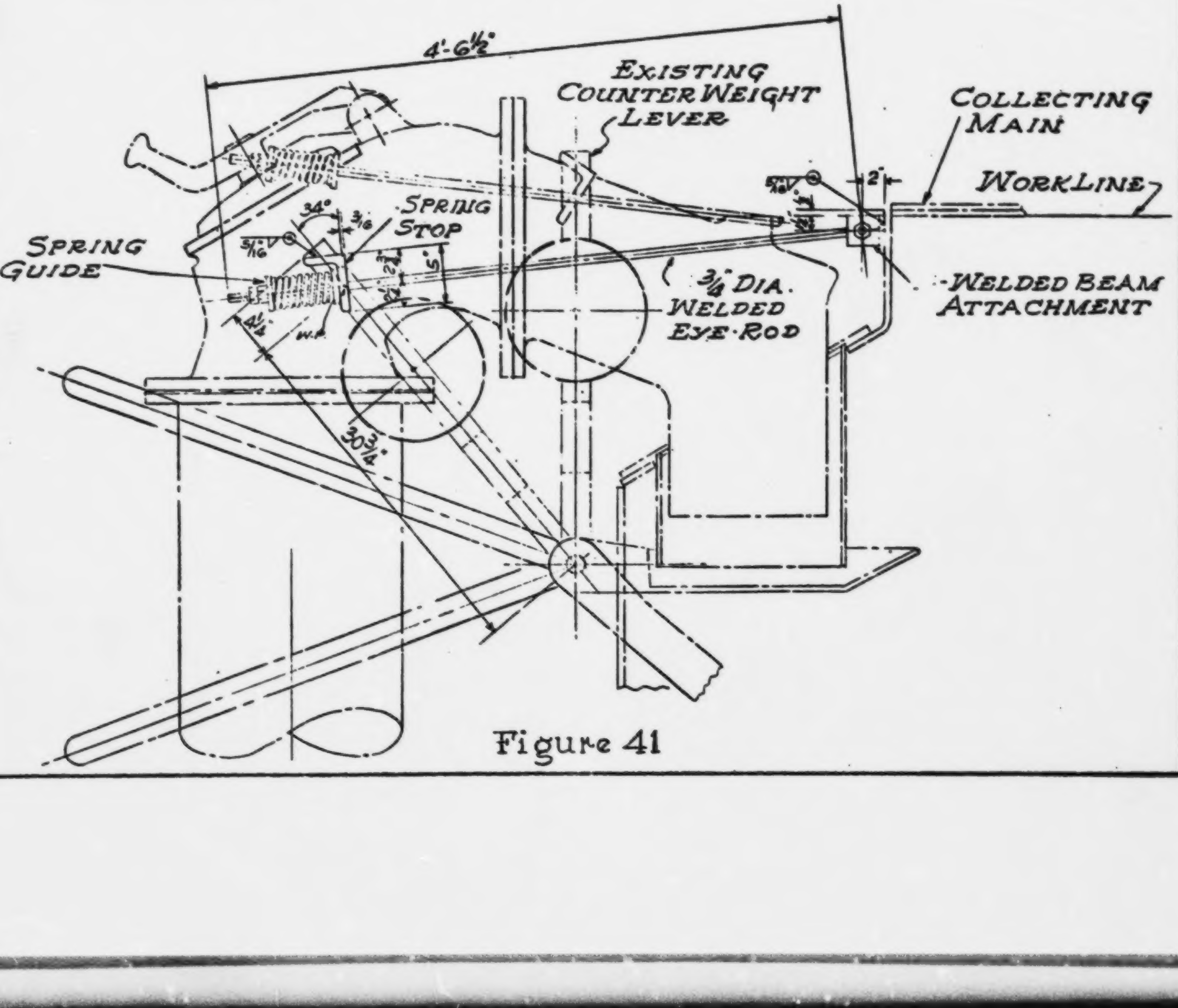
   A damper stop mechanism has been designed (Figure 41) that can be adjusted to take up some of the shock that would be transmitted through the damper shaft as the damper valve strikes the valve stop. The adjustment must be carefully made so that the spring receives the initial impact, but that it is not stressed sufficiently to prevent a proper liquor seal.

   Six of these mechanisms have been installed and are being evaluated. It is necessary that the adjustment requirements do not change with time, otherwise the shafts could be damaged before the need for re-adjustment is established. There are no apparent problems after three months operating experience.

2. There are some stiff dampers for which the damper lever does not free-fall as required by design. Some of these are stiff enough that they can not be operated properly with the larry car rotating levers. When these levers become this stiff, they cannot be operated from the car, and must be moved manually. About 6% of the linkages are in this condition now.

   Various means have been used to free the dampers. Several types of lubricant including penetrating oil and flushing liquor have been used without success. A very recent method, worked out by J&L maintenance, of spraying water on the damper shaft bearing outside surface has succeeded in freeing fifteen dampers. The difference in the expansion coefficients of the steel bearing and the cast iron housing resulted in sufficient separation to permit washing with penetrating oil. A final heavy application of lubricating grease resulted in a freely operating mechanism.

   When a damper can no longer be operated manually, it must be changed. This is a major job and requires removal of



DAMPER STOP MECHANISM

4'-6½"
Existing Counter Weight Lever
Collecting Main
WorkLine
2"
5/16
34°
3/16
Spring Stop
Spring Guide
5/16
2¼"
5"
4¼"
W.P.
3/4" Dia. Welded Eye-Rod
Welded Beam Attachment
30¾"

Figure 41

Damper Valve Operating Mechanism (continued)

2. (continued)
the standpipe. There have been approximately eleven dampers changed since May, 1972. This will no longer be necessary if the water application continues to work.

Since this problem had not been occurring previously, it is believed by some to be related to the AISI/EPA charging system. One theory is that the basic problem is the result of hard tar deposits on the Pullman damper shaft bearings. This could be the result of partially plugged liquor sprays and/or steam leakage. The increased steam pressure and gas flow rate results in less cooling from liquor sprays during charging. The tolerance to partially plugged liquor sprays is apparently decreased. The partially plugged nozzle and/or steam leakage will result in a localized high temperature condition in the collecting main. This can vaporize the light volatiles from the tar deposits which always exist in the damper bearings. When the liquor sprays are cleaned, and proper cooling takes place, the remaining residue of tar or pitch in the bearing area becomes very stiff or in some cases hard. This condition can occur as temperatures exceed 300° F for prolonged periods of time. The total condition can be further aggravated by the amount of coal or coke fines which are combined with the tar. Once the tar deposits start building up on the bearing surfaces the condition becomes progressively worse. Liquor sprays are now cleaned on a weekly inspection cycle.

There is also the possibility that a bent damper shaft could cause the problem by permitting the damper to be left in a slightly open position so that the liquor spray does not properly clean out the tar deposits from the damper. Since some of the dampers changed did not appear to have bent shafts of sufficient magnitude to prevent proper operation, at least most of the failures cannot be attributed to this cause.

Linkage Operation

The ability to control the operation of the ascension pipe linkages from within the enclosed cab of the larry car is very desirable. It minimizes the larryman's exposure to the battery and reduces the lidman's work. Achieving reliable operation at P-4 battery will be a difficult task. The required millwright maintenance to keep the linkages in operating condition will probably involve 8 man-hours per week.

In view of the difficulty with interference of the steam linkage with the lid linkages, the steam linkages will probably be removed. The larry car will then operate the damper and lid linkage mechanisms. The lidman will operate the aspirating steam valves and the jumper pipe valve.

GOOSENECK CLEANER

The original gooseneck cleaner was never used successfully. The mechanism required good alignment between the gooseneck and the charge car to be able to function. A survey along the ovens showed that the distance between the car and gooseneck (cross-battery) varied within a total band of 4". The corresponding elevation varied 3 3/4". When the car was spotted on the oven to be charged, the variation in gooseneck cleaner position and the gooseneck opening (oven to be cleaned is two positions south of the oven to be charged) is a band of 3". The cleaner could not be made to work under this set of conditions.

The cleaner was relocated on the car to obtain optimum positioning on a selected group of ovens, but still could not be used effectively. The variation of the position at which the cleaner rested on the bottom section of the gooseneck opening,and the resulting difference in the gooseneck travel angle rendered the device ineffective. The rotating disk and shaft would strike the inside of the gooseneck during operation in such a manner that resulted in it catching in the spray nozzles. A chain ratchet was required to pull it out. Since the combined efforts of J&L and Koppers personnel were not able to make this gooseneck cleaner function properly on this battery, it was decided to proceed with an entirely new design. The remote operation of a mechanized gooseneck cleaner was an essential part of this system.

SELF ALIGNING GOOSENECK CLEANER

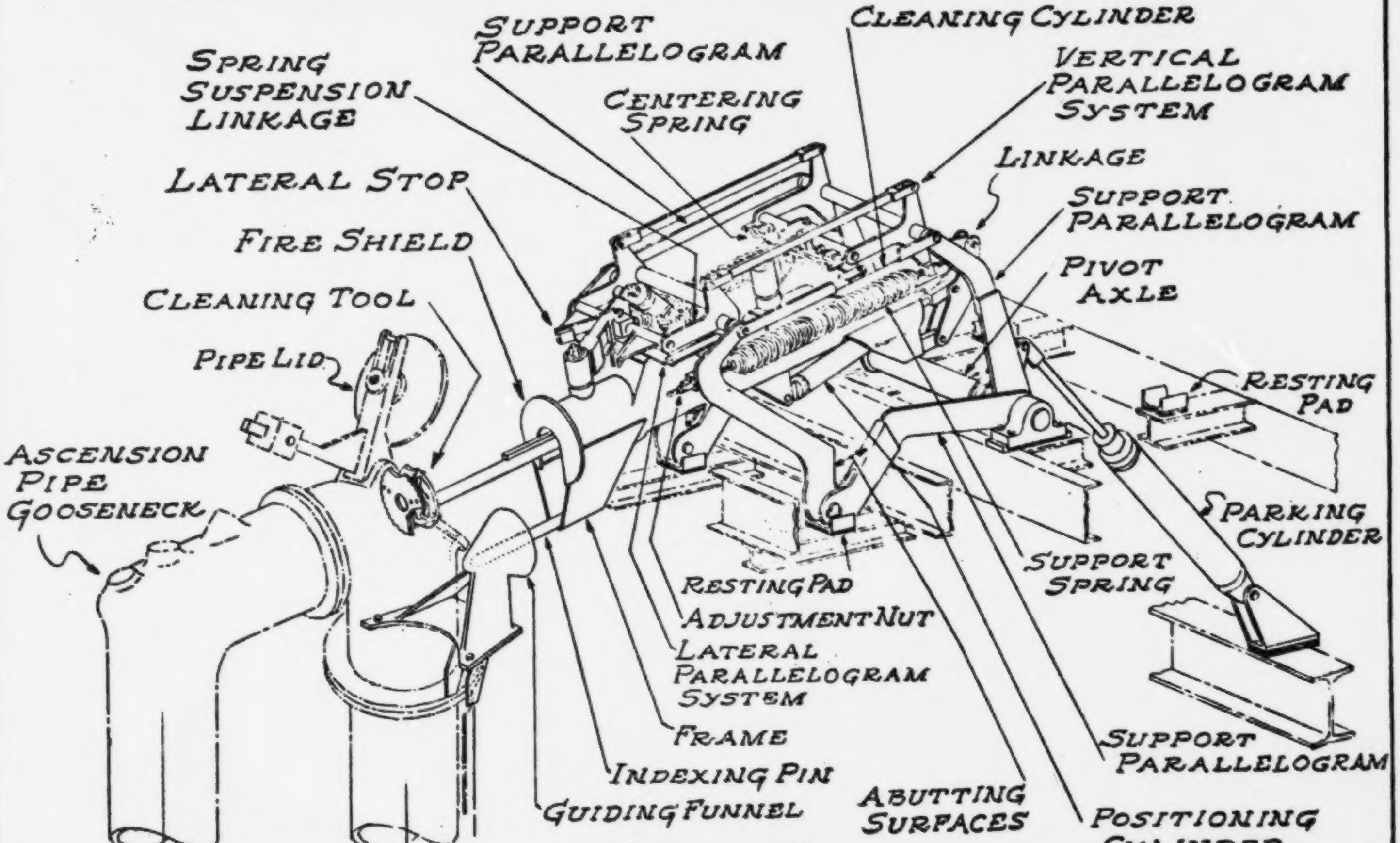

SUPPORT PARALLELOGRAM
SPRING SUSPENSION LINKAGE
CENTERING SPRING
CLEANING CYLINDER
VERTICAL PARALLELOGRAM SYSTEM
LINKAGE
SUPPORT PARALLELOGRAM
PIVOT AXLE
LATERAL STOP
FIRE SHIELD
CLEANING TOOL
PIPE LID
RESTING PAD
ASCENSION PIPE GOOSENECK
SPARKING CYLINDER
SUPPORT SPRING
RESTING PAD
ADJUSTMENT NUT
LATERAL PARALLELOGRAM SYSTEM
FRAME
SUPPORT PARALLELOGRAM
INDEXING PIN
GUIDING FUNNEL
ABUTTING SURFACES
POSITIONING CYLINDER

Figure 42

GOOSENECK CLEANER OPERATION DESCRIPTION

The gooseneck cleaner assembly is parked in an upstanding position (not shown) supported by pivot axle (4) and resting pad (5). In this position the assembly will not fall forward in case of cylinder failure since its center of gravity is safely past the pivot axle.

Cleaning cycle begins by pivoting the assembly by means of cylinder (1) from the parked position to down position where the support parallelogram (5) reaches resting pad (20). The remaining of the cylinder (1) stroke pushes the assembly to the forward working position shown here.

During forward motion from the down position to the forward position the assembly is guided into lateral and vertical alignment with the ascension pipe by means of guiding funnel (7) mounted to the ascension pipe and indexing pin (8) mounted on the assembly. The length of the forward motion from the down position to the forward position varies as inside end of funnel stops the indexing pin to the right relation with the ascension pipe.

As the indexing pin slides against the inside of the funnel and moves the cleaner assembly laterally and vertically, the parallel orientation of the assembly is maintained by means of a lateral parallelogram system (9) supporting the assembly and a vertical parallelogram system (10) supporting the lateral parallelogram system. Centering springs (11) provide additional help to gravity for centering lateral parallelogram system. Supporting springs (12) support the assembly through the vertical parallelogram system and can be adjusted to carry the assembly at a mean elevation by means of adjustment nut (13) at one end of each spring.

Frame (14) which is carried by the lateral parallelogram system, supports the cleaner cylinder (3) through two opposed linkages (15) and (16). When cylinder (2) is moving the cleaning cylinder (3) forward by means of pulling linkage (15), linkages (15 and (16) are pivoted in opposing curves about their fixed pivots mounted on frame (14) causing the cleaning tool (17) to dodge under the upper lip of the gooseneck opening while advancing from the down position to the forward position. (Linkages (15) and (16) and cylinder (2) may not be necessary when the gooseneck opening is designed to permit straight motion of cleaning the tool from the outside to the inside of the gooseneck.

The cleaning stroke of the cleaning tool inside the gooseneck as stated above is accomplished by stroking action of cylinder (3). During the cleaning stroke of an axially misaligned ascension pipe, the cleaning cylinder is permitted to be pushed off axis by means of a spherical joint connection at linkage (15) and a spring suspension system at linkage (16). After cleaning, all above described sequences are reversed to bring the assembly back to its parked position.

Note that when support parallelogram (6) is backed up to the parked position contacting surfaces (18) and (19) meet to force parallelogram (6) to swing upward about pivot (4).

FIGURE 43

GOOSENECK CLEANER (continued)

Design criteria were determined that would require the gooseneck cleaner to align itself to the gooseneck with a position uncertainty corresponding to a volume (5 1/2" vertical , 6 1/2" cross-battery, 3 1/2" north-south). The swab was to be a cookie-cutter type, 11 3/4" diameter, and remotely operable. The design is shown in Figure 42 and 43.

This unit was completely tested in the fabricator's shop using the electric and hydraulic controls and an actual gooseneck assembly. It met all design criteria during the final shop test on October 9th. The unit was received at J&L in early November and will be operationally tested in March.

TRACTION DRIVE

This drive permits the car to accelerate at maximum rate within the current limit of 200% load at a smooth bumpless rate. It was capable of 400 feet per minute maximum traverse speed. It was controlled without difficulty at 2% speed for accurate spotting over a charging hole with the car positioning system. The drive system has low backlash so accurate spotting is possible.

The performance of this drive system has been excellent and there have been no serious malfunctions in 16 months of production operation and 2 1/2 years exposure on the battery. Two failures involving regulator cards have occurred since it was installed.

There have been two minor problems with this system:

1. There were three failures with the traction drive caused by shorted wires to devices located externally on the larry car that were not actually part of the traction drive system. Those devices such as a warning bell and the stopping sensor were removed from the traction drive supplies, and now use independent supplies.

2. At the start of production operation suppression trip outs occurred at times. These trip-outs are not serious since the drive can be manually reset with a push button in the control room. These were found to have been caused by poor contact between the trolley contact shoe and the 460 volt

TRACTION DRIVE (continued)

2. (continued)
supply rails. The tension of the trolley pole was increased. Also capacitors were placed at the output of the phasing transformer. There have been negligible occurrences of suppressions in the past six months.

COAL CHARGING CAR POSITIONING SYSTEM

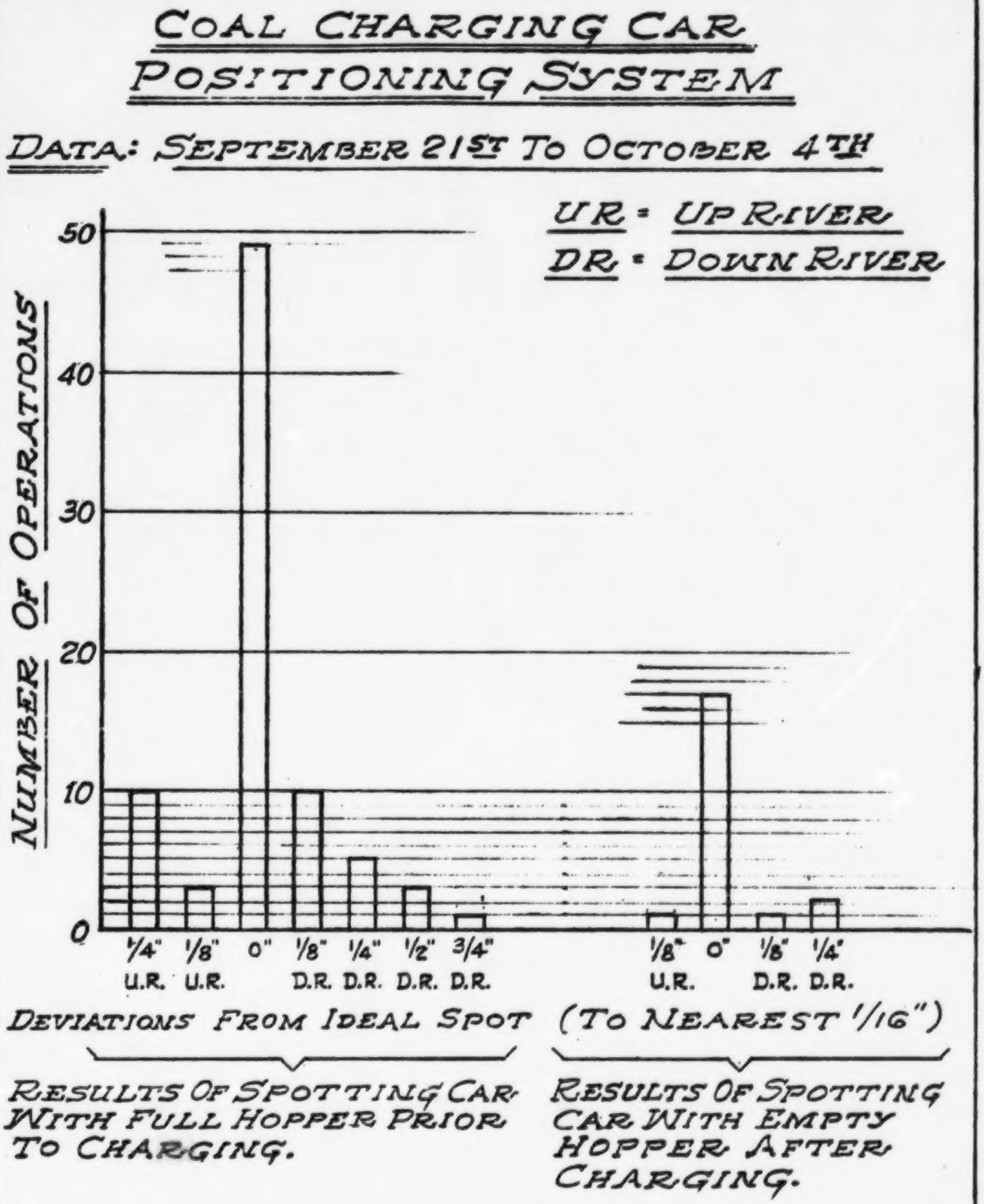
The automatic spotting system was used by the operators from the start of production operation in September 1972 through mid-January 1973. At the start of operations it was necessary to adjust the vane positions on many ovens. There was no significant adjustment of any vane from October through mid-January. The stability of the vane position of all ovens is known to have been satisfactory during that time interval. The vane limits (rated 149° F) on the car were occasionally subject to excessive heat resulting from flames during charging, which heat up the heat shield. One switch failed from excessive heat.

The positioning system stopped the car 95% of the time within ± 1/4" and almost all times within ± 1/2". This type of accuracy is satisfactory. Figure 44 graphically indicates typical spotting accuracy data.

When the car does not spot properly, the operator can get around the problem very easily. He either tries another auto spot, or he spots manually. With manual spotting used (gunsight positioning), a pushbutton is operated to tell the control logic that the car is spotted for charging.

In mid-January there were two accidents in which vane limits struck brass vanes. This caused permanent damage to several vane limits. It is not known how the vanes were bent out of place sufficiently to strike the limit. The vane limit has a "U" shape opening of 1 1/2". The brass vane is 1/8" thick. It is possible these vanes could have first been bent by something external. To the extent that this can cause severe damage to the limits, the system has undesirable features.

There are two significant advantages in having an automatic spotting system:



A.I.S.I./E.P.A. COAL CHARGING SYSTEM
P4 - BATTERY

Figure 44

COAL CHARGING CAR POSITIONING SYSTEM (continued)

1. It stops the car in an optimum position prior to initiating a charging sequence which depends on accurate positioning to function reliably.

2. There are times when it is difficult for an operator to see the proper spotting position, particularly when steam from the coke wharf is present. With the automatic system, this is not a factor.

In spite of these advantages in using the system, the problem of damaging vane limits as a result of uncontrolled conditions minimizes the utility of such a system. The operators have the ability to spot within ± 1/2" without difficulty in the manual mode using a gun-sight. The automatic system is no longer used at P-4 battery.

This automatic system can be successfully applied if a way can be found to prevent excessive damage from occurring when vanes get moved in such a manner that they strike the limit switch.

HYDRAULIC SYSTEM

In general the system has performed reliably. The pressure was increased from 1000 psi to 1300 psi to provide additional force to raise the drop sleeve. The system can be run continuously without overheating the hydraulic fluid. If the fluid temperature rises above 130° F, then it is time to look for excessive internal hydraulic leakage.

The life of the hydraulic valves and switches appears to be satisfactory. The problems with the hydraulic system relate to leaks and hose failures. The failures can be minimized by the judicious combination of piping with hoses to minimize hose exposure to heat and flames. The arrangement must be such that hoses can be easily replaced if they do fail.

Few of the original hoses are still in use on this car. A "GSM" heat-resistant hose manufactured by Goodall Rubber Company has performed as well as any tested. This hose has a double layer of woven asbestos insulation under the armor.

ENVIRONMENTAL CONTROL UNIT

The Environmental Control Unit has been a source of high costly maintenance. The dual inertia-type dust louvre clog easily and become coated with tarry material which is difficult to remove, thus resulting in serious reduced air flow and subsequent rise in temperature in the electrical control room. Frequency of cleaning varied from two to four weeks with occasional frequency as little as one week.

The replaceable bag-type filter had to be changed every seven to ten days at a cost of approximately $50.00 for each bag plus labor costs. Because of the design, considerable time was spent in removing the access plates in order to clean or change the filtering components.

In an effort to increase the useful life of the Dust Louvre and Dri-Pak, a disposable type filter (FARR Type 83, Glass Fiber Media, Class II) has been installed at the air inlet of the system behind the bird screen. This filter must be changed on a daily basis, but is easily accessible. Results, today, indicate that this pre-filter has significantly extended the life of the downstream Dust Louvre and Dri-Pak. The useful life of the Dri-Pak appears to have been extended sixteen to twenty days.

The pre-filter has eliminated the tar deposits which clogged the inertia-type dust louvre. This unit requires a monthly cleaning, but this is much easier in the absence of tar. The access plates have been hinged to shorten the cleaning or replacement time. Additional work is planned to improve the filter to further reduce required maintenance and improve the over-all removal of particulates.

Charcoal Filter

Despite efforts to evaluate the useful life of the activated charcoal filter by means of acceptable analytical techniques (% activity, % retentivity, % volatile content, etc.), no success has been achieved in deriving an evaluation procedure. The carbon steel housings of the charcoal trays corroded to such an extent that it was necessary to replace them with stainless steel trays. Subsequently, these replacement filters became clogged with deposits of ammonium sulphate which not only

Charcoal Filter (continued)

eliminated the effectiveness of the activated carbon but significantly reduced the total air flow through the system.

Specification Deficiencies

Performance evaluations made on this system indicate that it failed to meet the following specifications:

1. THE TIME-WEIGHTED AVERAGE CONCENTRATION OF 0.2 MG/M^3 OF COAL TAR PITCH VOLATILES (BENZENE SOLUBLE FRACTION) SHALL NOT BE EXCEEDED DURING THE NORMAL 8-HOUR WORK DAY.
   Environmental measurements made inside the larry car indicated the average time-weighted concentration of Coal Tar Pitch Volatiles (Benzene Soluble Fraction) in an 8-hour work day to be an average of 0.73 mg/M^3, ranging from 0.3 mg/M^3 to 1.02 mg/M^3.

2. 99.9% REMOVAL OF PARTICLES BY FINAL FILTER, DOWN TO ONE MICRON PARTICLE SIZE.
   Environmental measurements made inside the cab indicated the overall system efficiency to be 86.3%.

3. THE TIME-WEIGHTED AVERAGE CONCENTRATIONS OF CO SHALL NOT BE EXCEEDED DURING THE NORMAL 8-HOUR WORK DAY.
   No provision has been made for removal of CO in the Environmental Unit. Environmental measurements indicated that the time-weighted average concentration of 50 PPM was exceeded at least one of three working shifts sampled.

4. THE VENTILATION UNIT SHALL PRESSURIZE THE OPERATOR'S CAB OF THE COAL CHARGING CAR.
   Measurements made inside the operator's cab indicated no significant positive air pressure.

   With the lack of a weighted final louvre, perforated ceiling tile in operator's cab, and an unbalanced ventilation system, pressurization of the cab would require increasing the air delivery over its present capacity.

Conclusions

Although the system did not meet all the specifications, the working environment in this enclosed larry car cab is a significant improvement over an open cab. The location of the unit on the larry car at the pusher side of the car exposes the air inlet to pushing emissions. It had to be located there because of space considerations. If space were available on the opposite corner of the car (Fig.9-Pg.33) where the hydraulic unit is shown, its reduced exposure to emissions would significantly improve the performance.

ELECTRICAL SYSTEM

The collector rail system has been very adequate for the new larry car. The stainless steel has proved to be superior to the plain carbon steel rails. When the car travels along the battery, the static on the radio communication system is very pronounced at the plain carbon rail section and quiet at the stainless section. High speed recordings of the supply voltage on the car indicate a much steadier voltage from the stainless steel portion of the rails, as a result of superior contact with the collector shoes on the car.

Larry Car Logic

The sequencing control consists of solid state logic with outputs that control standard industrial solenoid relays. The logic control is divided into two sections - Automatic and Manual. These sections were made as independent as possible so that a fault in one would not be likely to affect the other one. They share input sensors (limit switches) and output relays. An AUTO-MAN switch at the console permits the operator to select the sequencing mode. There have been many AUTOMATIC charges made in which it was necessary to switch over to MANUAL mode to complete the charge.

After considerable operation on the system, it is believed that two independent logic sections are not necessary. Each logic cabinet has its own separate power supply. The equipment has proved to be reliable and separate power supplies are not necessary. If a relatively complex manual system of logic is to be furnished, similar to what was required on this larry car, along with an automatic system that simultaneously or sequentially initiates the various sub-operations, then the logic should be sectionalized as a minimum separation. The MANUAL logic should all be in separate independent sections. The AUTOMATIC logic would then provide initiating signals to the individual MANUAL logic functions. The MANUAL functions would supply signals to the AUTOMATIC indicating the status of completion. This arrangement would be simpler, and require less hardware than used on the AISI larry car.

Test switches were provided so that the logic sequences could be stepped through for trouble shooting purposes. These proved to be difficult to use effectively. Trouble shooting has been accomplished by observing the status indicating lights as the equipment is operated, usually at the south end of the battery in a "test" position. Other necessary tools are a volt-ohmeter to measure logic voltage levels. When a multiple choice of events can cause the trouble, logic elements can be grounded to COMMON to narrow down the possible sources of trouble.

The performance of the logic has been reliable. This is attributed in a large measure to the way in which it was designed and manufactured by General Electric. Logic level power sources and the COMMON lines are sufficiently heavy to maintain adequate levels. There have been few problems with inadequate contacts. One question raised in the initial design stages, related to the application of logic, was its performance in a coke oven atmosphere. To date there has been no general problem that has been caused by the oven environment. Connectors of the plug-in cards have a tin-nickel alloy plating. The connection at the card plug-in point is designed to be gas-tight. General Electric states that this type of connection has been tested in their laboratory to ensure its ability to withstand corrosion. This test consisted of three weeks in a 5% H_2S atmosphere over water.

The low voltage relays that furnish outputs from the logic are hermetically sealed. The fact that the logic equipment is designed to operate in an industrial atmosphere does not preclude the necessity to protect the hardware. The air must be conditioned. It is desirable that the temperature be

Larry Car Logic (continued)

controlled well within design limits so that local hot spots or marginal operations are avoided. The equipment must be enclosed and requires careful periodic cleaning with a vacuum.

In an effort to ensure continued equipment reliability the logic control is insulated from the outside world by using an isolation input element which has no electrical wired connection between input and output. The input sensors are applied at a voltage level of 105 V.D.C. There were a few problems associated with this device. It is mounted on a stationary back plate from a terminal block. There were occasions when a soldered terminal developed a crack which resulted in intermittent misoperation. The terminal board has since been re-designed by the supplier to provide a stronger mechanical joint and increased solder area. There were also several failures of the device itself caused by a poor solder connection to a transformer. This was a weakness in the design and has since been corrected by a modification. There have been no other types of troublesome logic elements, and the overall performance has been good. The output relay cabinet and the magnet controller cabinet contain standard industrial equipment that has performed well.

Electrical Equipment Reliability

In general the reliability of the equipment in the control room has been good, and the required maintenance is minimal. The major problems have been related to the equipment outside the control room. The sensors have been the least reliable part of the electrical system.

The following is a list of required external limit switches for control purposes on this car.

			TOTAL
1.	Lid lifter	(5)	15
2.	Butterfly oscillate	(3)	9
3.	Feed hopper position	(3)	9
4.	Coal level sensors	(1)	3
5.	Ascension pipe linkage operators	(4)	4
6.	Gooseneck cleaner	(2)	2
7.	Coal bin gate operator	(2)	2
			44

Electrical Equipment Reliability (continued)

The lever operated switches could not survive any exposure to flame. There were also problems with the operating levers sticking, or becoming loose. The lever operated limits (coal bin gate excepted) were changed to a "GO" - type proximity switch rated at 450° F supplied by General Equipment and Mfg. Company.

The application of this switch to sense feed hopper position did not improve the reliability to the extent desired. An improved heat shield was fabricated, and the reliability has been good since that time. There have been no problems since the proximity limits were installed on the ascension pipe linkage lever arms actuators.

The applications of this limit to the lid lifter did not improve the reliability to an acceptable level. The switches were still exposed to flames which caused failures. A recent improvement has been to wrap them with a high temperature insulating material as shown in Figure 45. The purpose of the insulation is to prevent heating the switch above 450° F. This modification to switches on #3 hopper and #3 lid lifter has not had a sufficient test period to evaluate. At this time there have not yet been any failures (3 months operation).

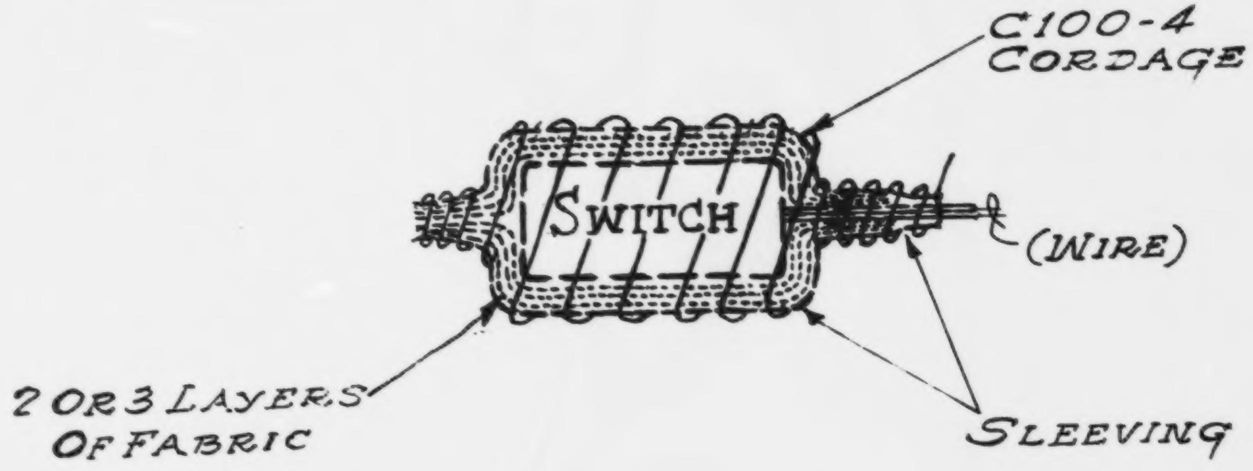
The limit switches were applied in two different types of circuits. All sensors that indicate equipment is in the "Travel Position" permitting the larry car to move, are part of the traction drive control. The supply voltage used in these control circuits is 115 volts a-c. These limits actuate relays with contacts supplying not only the necessary traction drive relay control, but also the sequencing static logic at 105 volts d-c. This creates two problems:

1. When electrical repairmen are working on limit switches they must de-energize both power supplies to remove to a potential hazard.

2. If multiple grounds occur in the sensors, there can be cross currents occurring between the 115 V.A.C. circuits and the 105 V.D.C. circuits that give unpredictable results.

A preferred method of design would have all sensors on the same supply circuit.

INSULATION OF PROXIMITY SWITCH


C100-4
CORDAGE
SWITCH
(WIRE)
2 OR 3 LAYERS
OF FABRIC
SLEEVING

1. SLIT THE C1554-96 (GREEN IN COLOR) "REFRASIL" CLOTH FABRIC TO THE DIMENSIONS REQUIRED TO COVER THE SWITCH.
2. WRAP ABOUT TWO TO THREE LAYERS OF FABRIC AROUND THE SWITCH.
3. SLIP THE "REFRASIL" SLEEVING OVER THE FABRIC.
4. USE THE C100-4 "REFRASIL" CORDAGE TO TIE THE SLEEVING.

Figure 45

Electrical Equipment Reliability (continued)

The service life of the Bin-O-Matic type sensor (75% coal level), which is used to indicate when leveling is to be initiated, has been adequate. Details of this device are discussed on page 112, Hopper Level Control.

The vibrators have a past history of failures. Most of the failures are believed to have been caused by wear in the bearing housing. Some of the failures are known to have been caused by excessive exposure to flame. The relocation of the vibrator on the hopper appears to have eliminated the excessive failure rate. Also the later style Martin Motomagnetic rotary electric vibrator model DVE-3500 is being replaced by an earlier style of the same mode. The earlier style apparently has better mechanical features.

The traction drive mill-type d-c motors, complete with permanent magnet type tachometers have required no repairs to date.

The performance and reliability of the external equipment will be considered acceptable if the life of the insulated proximity switch meets expectations and the vibrators continue to hold up well.

Larry Car - Pusher Machine Alignment

Originally a gamma ray interlock was considered. This system consisted of two sources of Cesium 137 enclosed in a shuttered holder so mounted on the existing pusher as to direct two collimated gamma ray beams to receivers on the larry car. Because of beam interference from the raw gas cross-overs, two pairs were required to ensure a clear sight line. Jones & Laughlin declined to use the system because of the necessary operating and maintenance requirements to comply with A.E.C. regulations.

The interlock actually furnished was an Ultra High Frequency system operating at a frequency of 10.2 GH_z, with a specially designed compressed antenna system. The arrangement is shown on Figure 21, page 54.

Larry Car - Pusher Machine Alignment (continued)

The system was developed to operate with the following design considerations:

1. Extreme variations in heat and atmospheric conditions.

2. Must operate through the existing and available line of sight conditions between the larry car and pusher machine. The line-of-sight conditions stipulated that an 8" x 8" opening was available at every oven, but that due to lack of perfect alignment between the machines, the system must operate with a 6" x 6" clear opening.

The following design factors are related to signal conditions:

1. The transmitter must develop enough power to low voltage levels to maintain a signal variation of 10 to 1.

2. The received signal must be adjustable to recognize a 500 micro-volt level for the pre-set distance of 20 feet.

The transmitter (48" long x 5" wide x 5" high) is mounted on the pusher machine with the antenna alignment designed for an 8" square opening between the pusher and larry car. The transmitter oscillator is an integral part of the antenna system. An indicating meter provided the operator with visual information that the transmitter was working.

The receiver (48" x 5" x 5") is mounted on the larry car. The antenna is a specially designed compressed type with a gain of about 4db. The antenna is coupled to the receiver by a wave guidesystem. The wave guide is a non-pressurized type. The receiver operates into a dc amplifier which provides an output voltage proportional to the received signal level. The amplifier drives a relay.

This system was checked out initially in a test position at the south end of the battery. It functioned properly at that time. No attempt was made to place it in service until the charging system was in operation. During this interval of time the equipment was severely damaged by the heat from burning gases.

Larry Car - Pusher Machine Alignment (continued)

The transmitter on the pusher, and the receiver and wave guide on the larry car would have to be replaced or completely reworked. The large expense involved in repairing the system could not be justified, especially since it was not suited to the environment.

It was also determined that the maintenance of an 8" x 8" opening at every oven would be very difficult. A preliminary survey, made before the larry car was built, had indicated that such an opening could be realized by moving certain obstructions. A later survey made with the actual equipment indicated that this could be done on approximately 90% of the ovens. The exact position of the pusher and the larry car with respect to the opening is subject to some variations with time. This system is not recommended for use as an alignment interlock.

Using single spot pushing and charging on the pusher machine and having available a voice communication system between the two operators minimizes the chance of charging the wrong oven. It does not prevent a larryman from starting a charge prior to the presence of the pusher machine. The problems involved in relying on proper operating procedures versus the maintenance expense and additional time required to use the available interlock systems must be carefully weighed in making the decision whether or not to use one.

Operating Modes

The AUTOMATIC and MANUAL operating sequences are described in Section V beginning on page 24.

Automatic System -

The AUTOMATIC sequence has not been used extensively. The principal problem is associated with the reliability in operation of the charging system components. The single AUTO CHARGE operation was not used because of reliability problems with the ascension pipe linkages. Movement of lever #2 to the UP position, as determined by a limit switch, did not guarantee that the linkage systems had been properly operated. With prepare-to-feed

Automatic System-(continued)

conditions satisfied, such as lever #2 UP, the charging of coal was initiated. However if the oven was not on-the-main (damper not open or standpipe cap not closed, or aspirating steam not on), it required some fast moves on the part of the operator to correct the malfunction.

The automatic system was difficult to use continually without reverting back to the manual mode of operation. The largest single factor was the lack of reliability in the coal feed system. The automatic mode initiates operations simultaneously or sequentially depending on the successful completion of previous events. The start of an automatic sequence, such as AUTO FEED, requires that related charging equipment be properly positioned initially. Once an operation starts, it can be canceled only by going back to MANUAL operation. If the coal flow fails to start in #2 hopper, the butterflies of #1 and #3 are closed until the flow in #2 is started. This requires switching to the MANUAL mode in order to close #1 and #3 butterfly.

If a butterfly stalls because the coal backs-up the charging hole during leveling. The AUTOMATIC mode would continue to attempt to operate the butterfly. This increases the chances of packing coal in the drop sleeve. With the manual mode the butterfly operation is terminated until the leveler bar removes enough coal.

Failure of a butterfly valve to close sufficiently to sense it with the limit prevented raising the drop sleeve to complete the automatic operation. Another problem was not getting all three drop sleeves UP when they were raised. This happened if there was too much coal left in the hopper. With MANUAL control the drop sleeves would be lowered again, the butterfly valve oscillated to charge the excess coal, and then raised. When charging with wet coal having 8% or more moisture, it is a normal procedure to empty excess coal from the drop sleeve to minimize the chance of coal packing on the next charge. There were so many instances where MANUAL operation was required, that it was impractical to charge with the AUTO mode.

Automatic System-(continued)

Another problem that was manifest with the use of the AUTOMATIC system was its inflexibility. The sequence of operations was frequently changed in order to determine the best charging procedure. The time at which the leveler bar entered the oven was changed. The leveler door was closed prior to re-lidding. Different charging procedures could be tried MANUALLY with no difficulty. Changed procedures with the AUTOMATIC MODE would require changes in the logic.

Manual System--

All charging operations are now done with the MANUAL mode. Indicating lights are provided so that the operator can monitor the performance of the operation. Each lid lifter has lights indicating the EXTEND, RETRACT, UP, DOWN position, LID OSCILLATE motion, LID IN CONTACT WITH MAGNET, and MAGNET ON-OFF. Without actually seeing the motions, the operator can definitely determine that a lid was actually removed and/or replaced, that the operation was properly sequenced, and that the lid lifter is in the travel position (UP and RETRACTED).

Sequencing of the lid lifter operation is subject to occasional failures in some part of the system, particularly sensors. An Emergency-Manual sequence is provided whereby individual motions can be initiated independent of the limits. The operators use this feature successfully.

Additional lights indicate the drop sleeve position (UP-DOWN), butterfly valve (CLOSE, OSCILLATE CW, OSCILLATE CCW), damper levers (UP-DOWN), coal level (TOP, 75%, EMPTY), vibrator (ON), and coal bin gate (OPEN, CLOSED). With these lights the operator can determine the status of the various mechanisms, even when they can't be seen.

With training the operators have been able to use the MANUAL controls without difficulty. The application and performance of the MANUAL controls is considered to be successful.

Successful Automatic System -

The approach to a successful automatic system first requires

Successful Automatic System- (continued)

a successful manual system. After the development of a consistent reliable manual system, then it would be feasible to attempt an automatic system, provided the gains of automation warrent the expense in achieving it. It is believed that the basic approach used on this system could be successfully applied under those circumstances.

Carrier Current Signal System

The AUTOMATIC operation required the use of the control signals between the charging machine and the pusher machine utilizing a carrier current pulse code modulated system.

This transmission system requires the use of a way-side loop for the charging car, and a second loop for the pusher machine. Originally as installed these two loops were one continuous loop. The signal losses at the pick up coil of the receiving machine proved to be too large for reliable operation. A repeater station was installed at the north end of the battery to minimize the losses. The signal at the repeater station is amplified so that it is re-transmitted at the same level as originally sent. It is necessary that the frequencies be different so that only one transmitter and receiver work together.

This is the first application of such a system to more than one moving vehicle. The system worked reliably as long as the equipment outside the control rooms was working properly. The principal problems were related to equipment damage as a function of its exposure to fires. The coaxial cable which connects the larry car antenna to the radio equipment failed twice. This type of cable is very sensitive to heat and it was necessary to reroute the cable so that its conduit was not exposed under the car. The coaxial cable which connects the pusher pick-up coil to the radio receiver also experience heat problems in the vicinity of the pick-up coil.

The wayside loop on the pusher side was located under the collector rails. The way-side cable supports were exposed to flame from an open chuck door. These supports would bend and cause the cable to be out of proper alignment and interfere with

Carrier Current Signal System (continued)

the pusher travel. If the automatic system is to be used consistently, this way-side loop must be re-located.

There were some initial problems with card failures within the pusher machine resulting from intermittent grounds. The power supply for the pusher machine is 250 VDC. Digital COMMON is related to this supply. This indicates one positive advantage in using the system with a 115 volt a-c supply where transformer isolation and grounding of COMMON can be done without difficulty.

Some additional logic cards failed in the pusher controls because the temperature inside the controller exceeded the rating. This was corrected by addition of a vent in the ceiling. A temperature thermostat was connected to an annunciator.

It is believed that this system can be made to function reliably if the external equipment (antennas, pick-up coils, wayside loop, coaxial cable) can be adequately protected from excessive heat and system grounds.

Voice Communication System

The performance of the systems has been good, particularly the larry to pusher system. The battery communication system at times is hard to hear because of a higher noise level. Its performance is considered acceptable, and the higher noise level is partly caused by the original existing system. The hardware utilizes transistorized circuits.

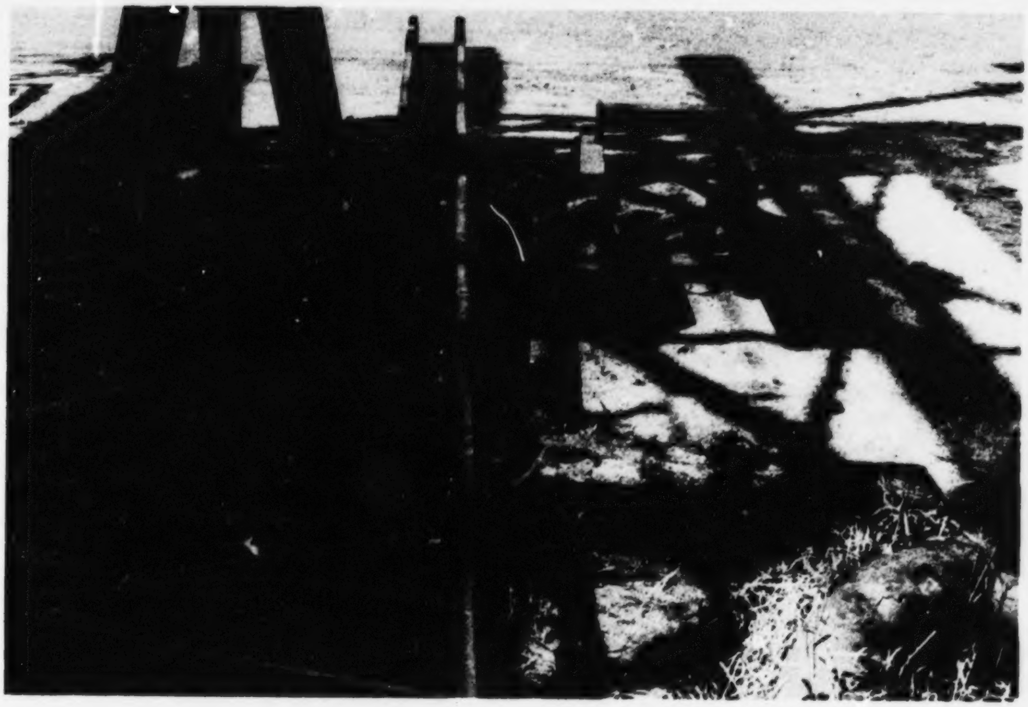
PUSHER MACHINE

Leveler Bar

After 15 days of operation, the new bar failed by becoming distorted so that the front end raised approximately 6 1/4", starting 20' back from the nose (Figure 46). At a distance of about 10' from the nose two top bulb sections of the bar buckled.

Based on a conclusion that the top of the bar overheated from oven radiation, while the bottom, riding on coal remained

OPEN WEB LEVELER BAR



OPEN WEB BAR SHOWING THE BUCKLING ON THE UPPER SURFACE ABOUT 10' FROM THE NOSE.

FIGURE 46

Leveler Bar (continued)

relatively cool a new design was made eliminating the side cut-outs to improve the heat transfer from top to bottom. A section of this later design, still using bulb angles for high strength, are shown on Figure 47. The bar was installed on May 20th and failed on July 16th by rising about 8 1/8" in the first 23' back from the nose. Refer to Figure 48.

J&L Research investigated the problem and concluded that the bar failure in bowing up at the end was caused by excessive temperature differential between the top and bottom of the bar.

The original bar has twice the web thickness as the self supporing bar design, and consequently better heat transfer characteristics. A study was made of this bar to determine if it could be safely used in the AISI/EPA system. An analysis of the allowable stresses in the original bar design indicate that the bar is self-supporting in use up to a maximum operating bar temperature of 1100°F. It was found from test data that the leveler bar temperature will not exceed 1000°F if the initial temperature does not exceed 800°F and the leveling time does not exceed 3 minutes. Refer to Appendix C for details of the leveler bar investigation. The original leveler bar has been in continual use since July 16, 1971. On May 2, 1973 it bent up about 6" in a manner similar to the previously described failures. At the time of failure a different larry car was in service and the leveling time was assumed to have been excessive. Koppers was requested to investigate a leveler bar design that would be less sensitive to prolonged exposure times in an oven. The results of their study recommended the use of a bar material corresponding to ASTM A-517-68, grade K quality, which manifests high yield strength at elevated temperatures. Cost data is shown on table 14, page 191.

Leveler Bar (continued)

The cost data in Table 14 is given for grade J steel which differs from grade K essentially in having a lesser amount of manganese (.41-.74 versus 1.05-1.55). Either of these grade steels has a yield strength of approximately 20,000 psi or better at 1150°F. Grade-J steel may be readily welded in thicknesses of 1 inch without pre-heat, provided the weld heat input is at least 30,000 joules/inch. Grade-K steel does not require pre-heat in 1 inch thickness for typical compositions, but if the carbon and manganese contents are close to the maximum, a weld heat input of 60,000 joules/inch, or 200°F pre-heat may be required to assure freedom from heat affected zone cracking.

Improved heat transfer characteristics (top to bottom) might be realized using wedge shaped side plates. Instead of having a rectangular section of 3/4" x 10", without changing the weight or area, the top thickness would be increased by 5/16 and the bottom thickness would be decreased by 5/16 (Figure 49). This concept has never been tested in actual service. The use of a leveler bar of the conventional design but utilizing the improved material would be this writer's preference.

The proper use of the leveler bar is required to minimize emissions. The stroke of the leveler bar was automated so that

LEVELER BAR
BULB ANGLE
CROSS SECTION

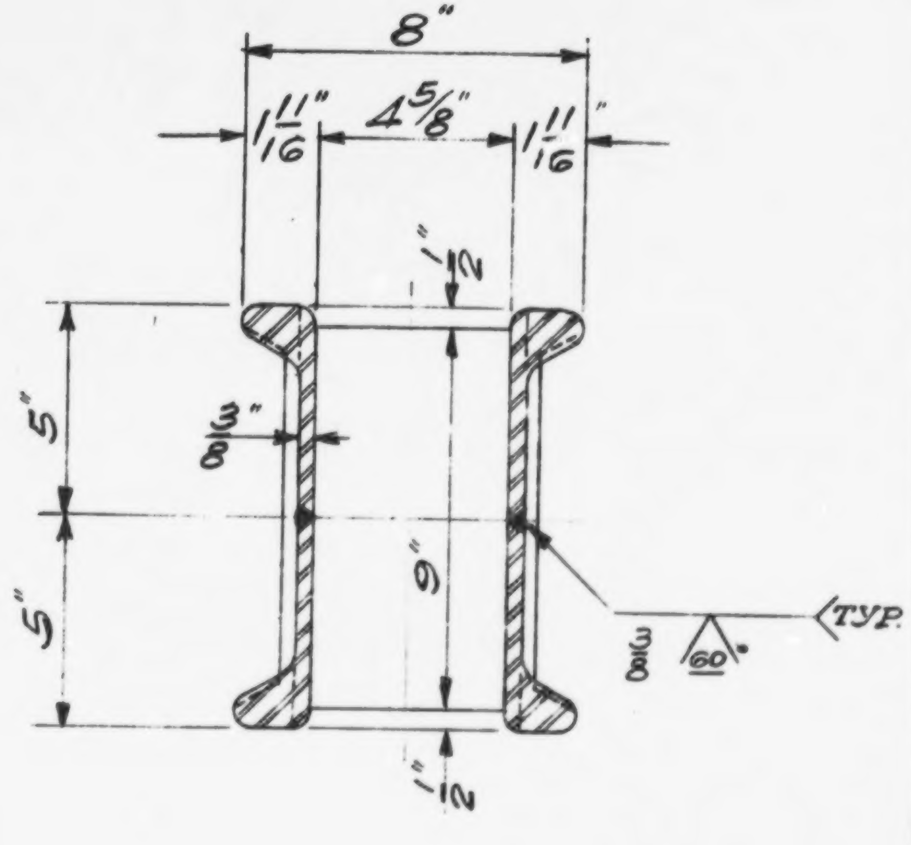
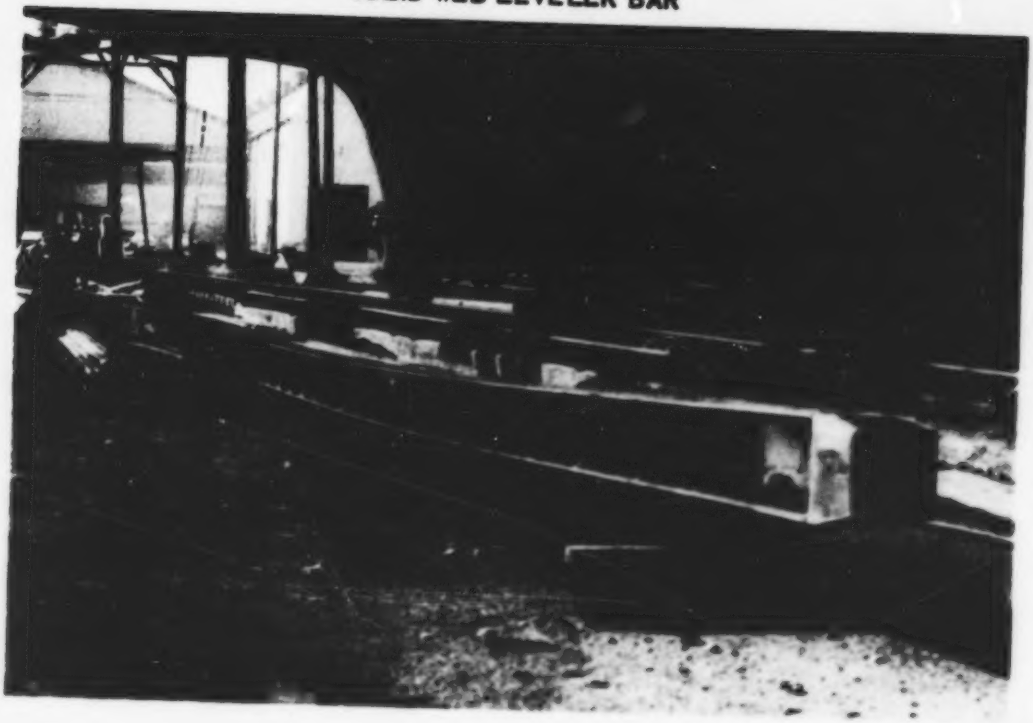

8"
1 11/16"
4 5/8"
1 11/16"
1/2"
5"
3/8"
5"
9"
1/2"
3/8
60°
TYP.

Figure 47

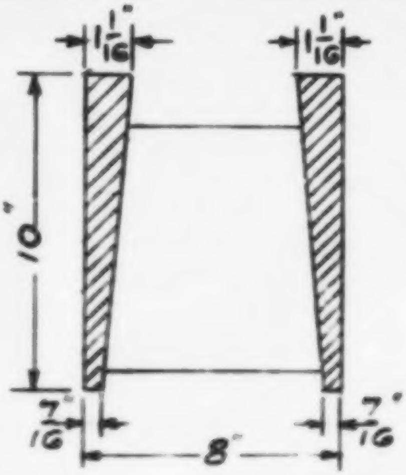
SOLID WEB LEVELER BAR



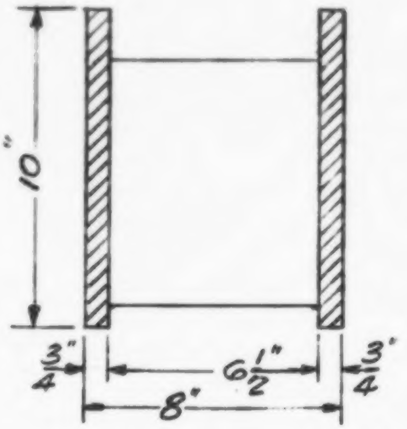
SOLID WEB LEVELER BAR SHOWING THE VERTICAL RINSE AT THE NOSE END

FIGURE 48

WEDGE SHAPED LEVELER BAR


1/16"
1/16"
10"
7/16"
8"
7/16"

WEDGE SHAPED LEVELER BAR
CROSS SECTION


10"
3/4"
6 1/2"
3/4"
8"

CONVENTIONAL LEVELER BAR
CROSS SECTION

Figure 49

Leveler Bar (continued)

it would always extend to the maximum stroke into the oven and then cycle with a 9 foot stroke and provide maximum leveling under #3 charging hole. The leveler bar makes about 8 cycles in a minute or about 135 ft./min. average. With the addition of jumper pipes, the leveling will be done under #2 charging hole, and the automated stroke will be increased to about 20 feet.

Efforts were made to increase the gas passage way in the oven during leveling by cutting about 2" from the top of baffles between the 3/4" side plates, and 3" from the top where the plates are 1" (refer to Section VI, page 75).

Leveler Bar Smoke Shield

The smoke shield was replaced in July, 1973, by one with a modified design. The leveler bar used to bind inside the smoke shield partly because the leveler bar can bend slightly during normal service, and partly because the smoke shield side plates buckled from the heat. The top of the original smoke shield had to be opened up to provide adequate clearance. The present smoke shield has inside dimensions corresponding to 9" in comparison to the original 8 1/2" opening (leveler bar is 8" wide).

The leveler bar had a tendency to even catch the side of the later model during leveling. This would pull it back away from the oven. The counterweight which forces it against the leveler door would cause it to return at great force when released and would hit the door frame with excessive impact. A device was made and installed by J&L maintenance that will prevent the smoke shield from being pulled back more then 1" during normal leveling. A method has to be found to prevent this 1" opening during leveling. There are some emissions from this port during charging (single gas off-take).

Leveler Door Operation

Originally the intent was to open the leveler door manually while the pusher side door was on the extractor. Stop detents were provided to hold the door in the open position so that when the pusher side door was replaced on the oven, the leveler door would remain open so that an air draft would decarbonize the standpipe. Later when the oven was to be charged, the pusher machine smoke seal would be placed against the open leveler door. After charging the operator would then close the leveler door.

In actual operation the detent pins would not hold the door in the proper position. Many of the detent holes were not drilled in the correct location. A revised operating procedure was worked out to by-pass the problem. The door is manually opened on the extractor and then relocated without latching, with the back of the cam on the handle touching the hook plate mounted on the door. This leaves sufficient opening for standpipe decarbonization, and requires only that sufficient door friction hold it in place. When the oven is ready to charge, the "door open" sequence is used. The mechanism is able to open the door from this position, if the cam stays in contact with the hook plate. This was accomplished by adjusting the operator timing to over-lap the closing and latching motions so that the operator pin is not raised behind the door loop.

There were many problems encountered in the initial operation of this device. During November, 1971, a Koppers representative reviewed all problems involving the failure to operate properly, and corrected as many as possible. Previously, a 3-inch latch cylinder had been replaced by a 4-inch latch cylinder to provide additional latching force. The major causes of mis-operation, as determined by Koppers, were as follows:

1. Improper fabrication of some of the leveler doors which made latching of doors difficult, and caused interferences in some cases.

2. Measured distances between the door opener unit and the doors varied up to a maximum of 4" both laterally and "in and out". The unit was designed to operate within a 2-inch square. The variation in relative spacing can be the accumulated errors caused by:

    a) Differences in rail elevation, or bowing of pusher machine rails.

Leveler Door Operation (continued)

- b) Expansion of the battery.
- c) Variations in placing of doors on the oven.
- d) Variations in spotting the pusher machine (one spotting position is used for the door extractor, pusher ram, leveler bar).
- e) Door operator may not be located in the most optimum position.

3. Tar deposits on the inside of some doors caused difficulty in closing (ovens were on long coking times when this check was made).

As a result of this investigation, the chuck door operator was relocated to an optimum position. The hook and hook pocket were ground on about 50% of the doors to facilitate closing and latching.

The adjustments on this unit must be very carefully made to insure proper operation on all doors. This is related to the variation in the position of the operator with respect to the door.

More recent problems involved the replacement of leaking air hoses. The original hoses were rated for a maximum of 200°F. Those hoses cannot survive that environment. J&L replaced them with the "GSM" heat-resistant hose. Hose performance is now considered satisfactory.

The engage pin rotate return spring has a tendency to lose its spring force as a result of the exposure to flame. This spring has been replaced twice.

The chuck doors are now lubricated every six months to minimize the force required to operate them.

While pushing an oven, an air jet at the top of the pusher ram is directed at the oven roof to remove as much carbon as possible. The amount of air used during this operation causes a 20-30 psi drop in air pressure. The leveler door operator uses the same air source. The door closing operation takes place just after pushing, before the air compressor has sufficient time to restore normal pressure. The drop in pressure reduced the available door closing force sufficiently to prevent consistent proper closing of tight doors. An auxiliary air storage tank with a check valve was furnished just for the leveler door operator that maintains sufficient minimum pressure at all times.

There have been some problems with the seal of the leveler door. The spring which forces the edge of door to seal around the leveler door frame is not designed for the high temperatures encountered on this battery. It has an upper temperature range of approximately 425° F. The springs are subject to 500° to 800° F with the heat shield on the door.

A program is underway to check all leveler door springs when the pusher side door is removed for maintenance. If the leveler door spring has a permanent set of 1/8" or more, the spring is replaced. In all cases, a 1/8" asbestos gasket is installed between the door and the spring.

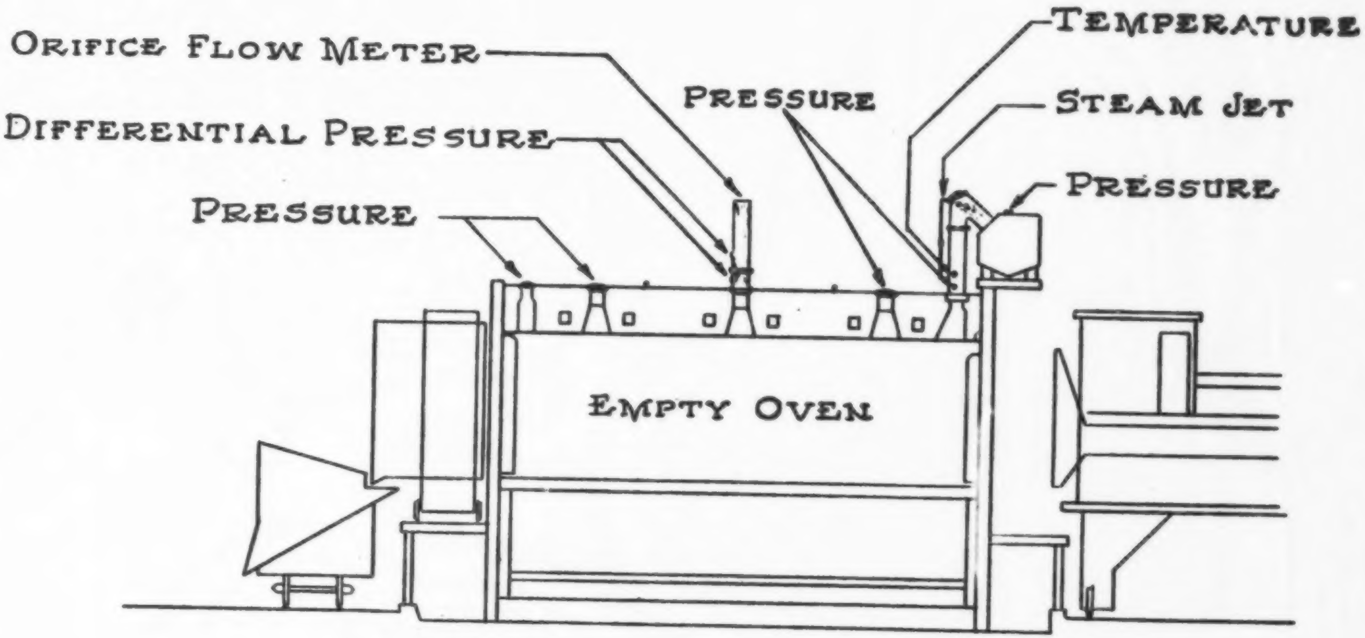
The performance of the leveler door operator is now considered satisfactory.

BATTERY MODIFICATIONS

Steam Ejector System

The development of an ascension pipe design that functions as an efficient steam ejector was the primary goal of an extensive test program. The design effort was limited to apparatus which could be installed without requiring oven or gas collecting main modifications. Eight models representing four major ascension pipe designs were tested on operating ovens at P-4 battery. These tests (Figure 50) consisted of measuring the air flow through one open charging hole in an empty oven (693 cu.ft.) as a function of steam pressure and temperature at the high pressure side of the steam nozzle. The charging hole lids and the standpipe cap were sealed with mud. High pressure super-heated

EMPTY OVEN TESTS


ORIFICE FLOW METER
DIFFERENTIAL PRESSURE
PRESSURE
PRESSURE
TEMPERATURE
STEAM JET
PRESSURE
EMPTY OVEN

TEST ARRANGEMENT TO MEASURE FLOW RATE AND SUCTION PRESSURE

Figure 50

steam (200 psig, 500° F) was supplied from an auxiliary 4" header. A test run consisted of taking vacuum measurements and air flow measurements with different size nozzles at various steam pressure settings.

Tests made on the existing ascension pipe were used as the basis for comparing new designs. The air flow test results for the four major designs are shown in Figure 51. The air flow measured by the orifice flow meter is shown as a function of thrust. The relation between thrust and pressure is given in Appendix E, along with the air flow equation.

The most efficient ascension pipe (design D) was a ceramic lined venturi-shaped standpipe with a steam nozzle made from 2 inch, double extra heavy, #316 stainless steel pipe. During every test the oven vacuum would reach 7.6" of water gage with approximately 95 psig steam, and would not go higher. Since the pressure transducers were capable of reading 8" of water gage vacuum, it indicated a limiting condition of oven vacuum. At steam pressures above 125 psig the standpipe cap had to be held down.

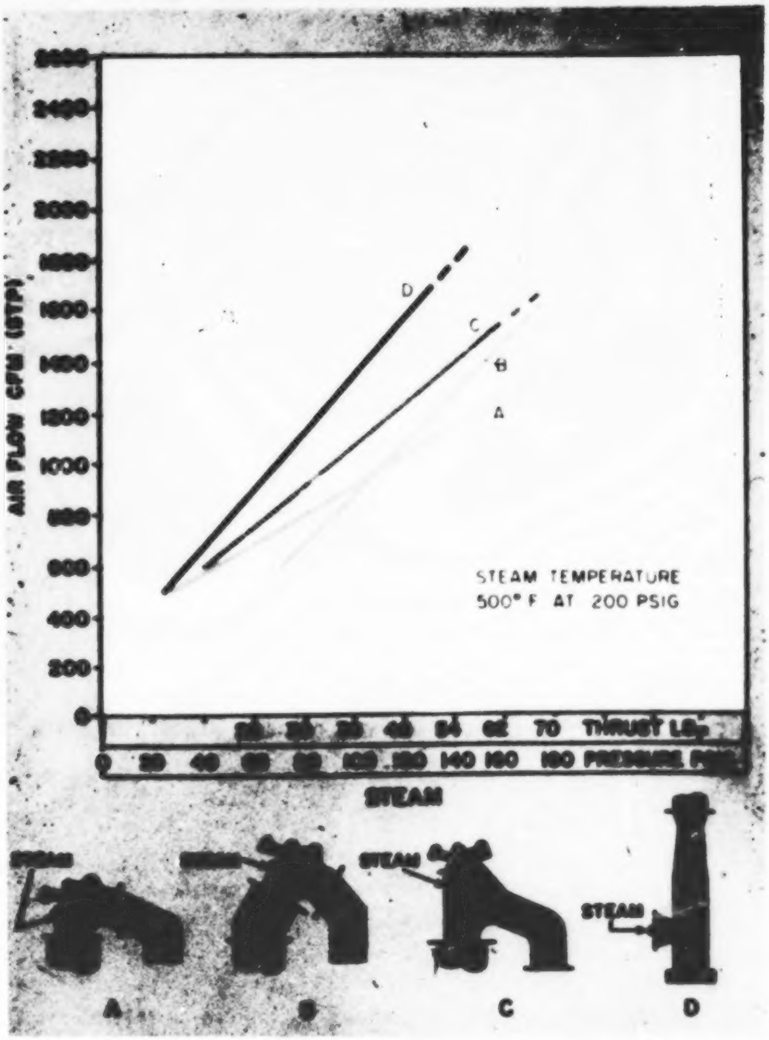
It was left in normal service (used original existing steam nozzle) to determine the life of the venturi steam ejector materials. After a couple of months the venturi steam nozzle was burned and no longer operable. More development work would be required to make a production model.

Design "B" used a modified version of the existing gooseneck with a lined standpipe extension. The location of the steam ejector was improved over the existing design. The liquor sprays were relocated so they washed the walls of the return bend.

Design "C" included the improved features of liquor spray relocation, smooth flow geometry and a concentrically located steam nozzle. The carbon formation in this design was less than in the existing design "A", or the modified design "B". The steam ejection performance is slightly improved over design "B".

Tests were performed to determine the equivalent gas flow

ASCENSION PIPE EJECTOR PERFORMANCE



DESIGN "A" REPRESENTS THE EXISTING DESIGN
DESIGN "C" REPRESENTS THE NEW DESIGN
ALL DATA TAKEN USING 5/8" STEAM NOZZLE. PRESSURE MEASURED AT STEAM NOZZLE. AIRFLOW MEASURED WITH ORIFICE FLOW METER AT #2 CHARGING HOLE.
FIGURE 51

required to contain emissions during normal charging. High pressure steam was connected to the ascension pipe, and emissions during charging were observed. Since the oven openings were not sealed, an equivalent test could not be made. Based on these observations a minimum gas flow of 1500 SCFM appeared to be required to charge a properly sealed 700 cubic foot oven at a 90 second charging rate.

The air flow data shown on Figure 51 is based on a 5/8" steam nozzle. In order to use the existing ascension pipes without modification the steam nozzle size was increased to 3/4". For a given pressure this would increase gas flow as much as 40%.

Super-heated steam was provided from a 4-inch header at 175 psig and 450° F. A pressure reducing station was supplied so that the steam pressure could be adjusted to the optimum valve. The piping to individual goosenecks was sized to provide 160 psig at the high pressure side of the steam nozzle. From the data of Figure 51, this corresponds to approximately 1200 SCFM for a 5/8" nozzle or up to 1680 SCFM with a 3/4" nozzle.

Five ovens were equipped with design "C" ascension pipes so that a performance comparison could be made with the existing goosenecks. The steam nozzles were made 11/16" diameter to obtain similar gas flow as the original design "A" goosenecks.

The new design gooseneck did result in minimal carbon formation. The carbon deposits were normally soft and easily removed. The operating personnel did not like cleaning these goosenecks because they were higher and not accessible for manual cleaning in a conventional manner.

The flushing liquor spray connections were not as easily cleaned as the original ones. This part of the design should be revised for easy removal by non-skilled employees, rather than requiring a craft such as a pipefitter or millwright.

The steam aspirating qualities of the new goosenecks are similar to that of the original design (the existing goosenecks use more steam since the nozzles are larger) and consequently the new design will be removed so that only one type is used. The mechanized gooseneck cleaner can be used only on the existing type ascension pipe.

Clean Ascension Pipe -

The passage way for the gases must be maintained open. Carbon deposits must be removed from the standpipe and gooseneck. When less than 80% of the opening is clear, the effect on oven aspiration usually is noticeable.

If the normal decarbonization cycle does not result in removing all the carbon deposits, the standpipe must be kept open by poking the carbon loose with long steel rods inserted from the top inspection cap. The gooseneck is cleaned prior to charging with a swab. An operating mechanized gooseneck cleaner will help this operation.

Self Cleaning Steam Nozzles -

The self cleaning steam nozzles installed on P-4 battery had three significant problems:

1. The rod broke on several of the nozzles where the cotter-pin is located.
2. Steam condensate sprayed out the rear end of nozzle when the steam was turned on.
3. The carbon build-up in the gooseneck had a tendency to bridge over the nozzle, thus severely restricting the steam jet.

The first problem occurred because the return spring operation resulted in impact stresses that were excessive. A maximum of four Belleville washers were added to the existing rod to reduce the impact. This number of washers proved to be insufficient.

It was determined that a modified design was necessary to correct the problem. The rod design was changed so it could accommodate additional washers. An improved method of removing condensate and reducing steam blowback through the cylinder end was provided by the addition of a second piston (Figure 52). The push rod, upon being released, will extend further into the oven before retracting to its normal position (1/16" past the end of nozzle). It was hoped that this additional penetration of the rod would help break up carbon formation.

The results of this later modification indicate that steam leakage past the piston rings is still excessive, and this type of construction is not suitable.

An additional nozzle was made that extends an additional 1 1/2" into the standpipe. For over three months this nozzle has not experienced a problem with carbon build-up. It has been tried in two different ovens with no problems. More of these nozzles will be tried.

The present practice at P-4 battery is to manually ream out each nozzle weekly.

Ascension Pipe Elbow Covers -

Six designs (Figure 53) were built and tested on P-4 battery. None of them achieved any significant improvement over the existing standpipe cap. No further testing has been attempted.

The seating of the existing caps was improved somewhat by reducing the play between the elbow cover and the elbow cover hinge by inserting washers. This causes the lid to close in a repeatable pattern. The present lid design will seal within 10 minutes at least 80% of the time. The present practice is to wet seal when necessary after the charge. This consists of pouring mud around the perimeter of the cap to seal all openings.

Charging Hole Lids

This lid performance has been satisfactory. One-quarter inch was removed from the lugs to increase the clearance between the

DOUBLE PISTON SELF-CLEANING STEAM NOZZLE

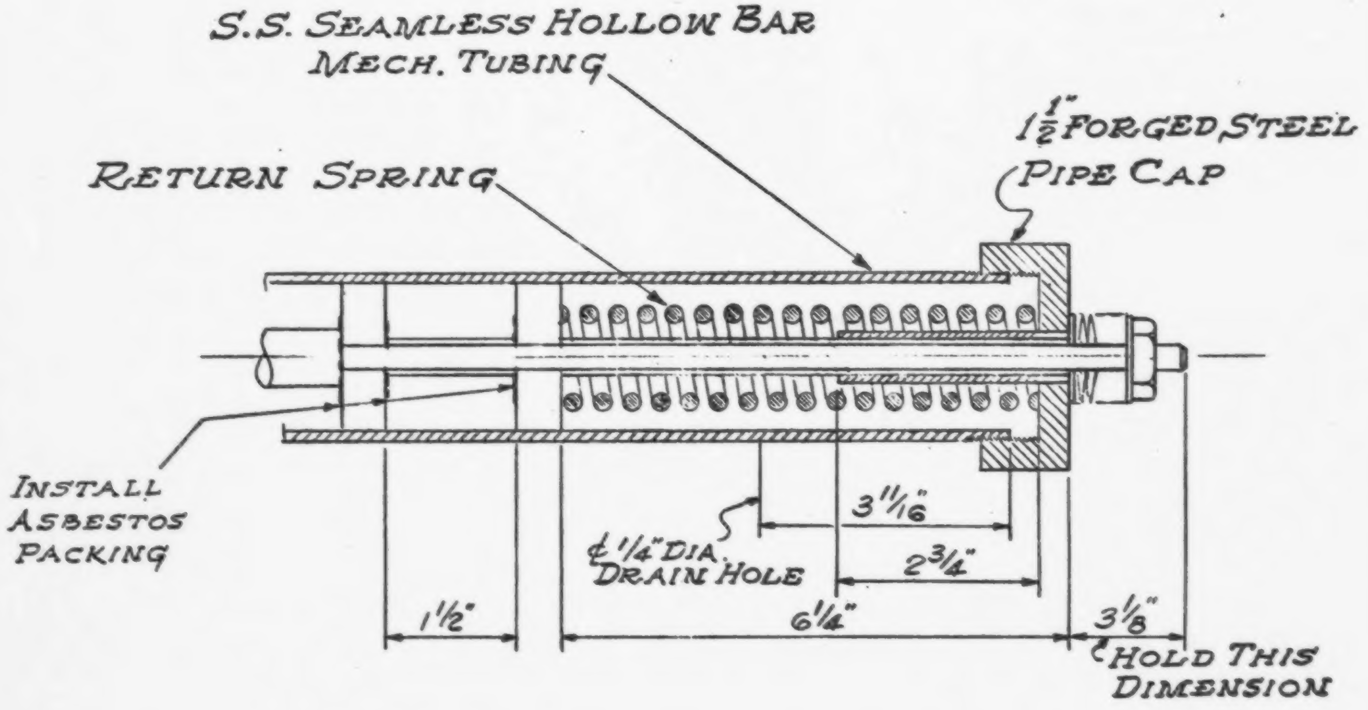

S.S. SEAMLESS HOLLOW BAR
MECH. TUBING
RETURN SPRING
1½" FORGED STEEL
PIPE CAP
INSTALL
ASBESTOS
PACKING
℄ ¼" DIA.
DRAIN HOLE
3 11/16"
2¾"
1½"
6¼"
3⅛"
HOLD THIS
DIMENSION

Figure 52

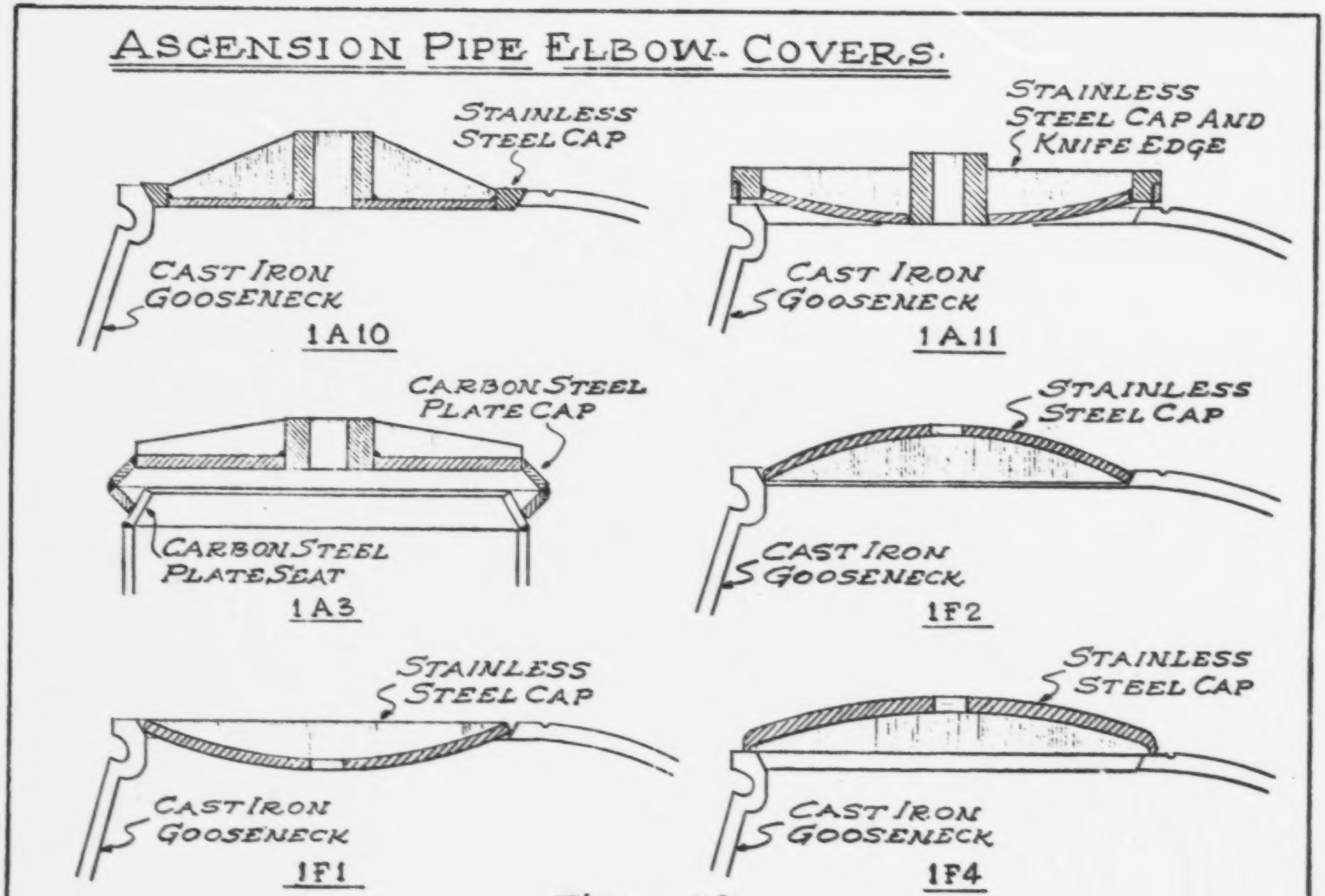

ASCENSION PIPE ELBOW- COVERS.
STAINLESS STEEL CAP
CAST IRON GOOSENECK
1A10
STAINLESS STEEL CAP AND KNIFE EDGE
CAST IRON GOOSENECK
1A11
CARBON STEEL PLATE CAP
CARBON STEEL PLATE SEAT
1A3
STAINLESS STEEL CAP
CAST IRON GOOSENECK
1F2
STAINLESS STEEL CAP
CAST IRON GOOSENECK
1F1
STAINLESS STEEL CAP
CAST IRON GOOSENECK
1F4

Figure 53

lid lifter magnet and the top of the lid. This also permitted the lid to be oscillated in the charging hole ring without undue interference with the lugs in the rings.

The radial grooves in the lids permit positive engagement with the lid lifter magnet, so that the lids are assured of rotating. The lid lifter is able to properly seat the lids.

Oven Alignment

The proper alignment of all battery mounted equipment with respect to the charging car was a necessary and time consuming job. The following must be simultaneously considered in making a determination of the proper position:

1. Car spotting panel is located to stop car in the desired position.

2. Charging hole rings must be relocated so that the drop sleeve fit concentrically when lowered.

3. The ascension pipe linkage of the oven to be charged must be adjusted so that linkage levers and the steam valve actuating mechanism are properly located when the actuating lever (#2) on the charging car is raised.

4. The ascension pipe linkage of the oven that is to be pushed (two ovens south of the one being charged) must be in proper position so that when the actuating level (#1) on the charging car is lowered, the damper valve closes and the standpipe cap opens.

5. The gooseneck location of the oven to be pushed must be in the proper position so that the gooseneck cleaner is able to enter and effectively clean the deposits of tar and char from within the gooseneck.

Satisfying all these requirements simultaneously was a difficult task. P-4 battery was placed in operation in December 1953. Batteries characteristically grow with time, and the original dimensions change non-uniformly. This dimensional

Oven Alignment (continued)

distortion required additional efforts to ensure that alignment tolerances were adequate for proper operation on this system. Details of the dimensional changes on the battery are given in Appendix F.

The general procedure followed in optimizing the car position at a particular oven was to free the existing charging hole rings from the permanent brick. The car was then positioned for charging this oven by aligning the gooseneck cleaner drive tube and flail with the center of the gooseneck inspection port. Thus the ideal reference point between the car and the battery was at the gooseneck of an oven two spaces south of the one where charging holes were to be relocated. The larry car drop sleeves were lowered so that the charging hole rings could be concentrically positioned. Movement of charging hole rings was limited so that no constriction was made in the charging hole. For those few cases where a limit was reached, the reference position at the gooseneck cleaner was moved away from the ideal. The car spotting panel was then mounted so that the car would always stop within ± 0.35" of this position. The ascension pipe linkage was adjusted for optimum operation.

Results -

It was possible to relocate the charging hole rings on one oven per day. The occasional problem with drop sleeve seating in #3 charging hole ring is the result of not being able to ideally locate the ring. It was usually necessary to reposition the car spotting panel to achieve optimum spotting. The ascension pipe linkages were then modified as necessary to obtain satisfactory operation. This consisted of bending the linkages and adding extensions to some. On some ovens proper operation was never consistently achieved because of the interference between the steam linkages and the damper linkages, and the wide variability in critical dimensions.

SECTION IX

APPLICATION TO NEW BATTERIES

The choice of charging equipment to be used on a new battery must be based on conditions that are expected to exist twenty years or more after it is placed in operation. Consideration would be given to improving the environment of the personnel working on the battery top. This would recognize the improvements of coking equipment that essentially result in smokeless charging, smokeless pushing, and minimal coke oven door leakage. The success in achieving this improved environment depends to a great extent on the reliability of the equipment involved.

Assuming the charging system utilizes a larry car, many of its operations would accordingly be mechanized. The AISI/EPA concept of controlled oven gas pressure requires the use of a double gas off-take and a good steam aspirating system.

CHARGING CAR

The charging car would have most of the following features:

1. Enclosed operator's cab.
2. Environmental control unit.
3. Coal feed system.
4. Drop sleeves.
5. Lid lifters.
6. Ascension pipe damper mechanisms.
7. Gooseneck cleaner.
8. Coal bin gate operator.
9. Electric and hydraulic power.
10. Automation.

Enclosed Operators Cab

The location of the cab on the charging car is an important operational factor. It can be at the battery level (LOW) or at an upper level (HIGH) suitable for cleaning goosenecks. The following table summarizes some of the features of either location.

Enclosed Operators Cab (continued)

Feature	High Level	Low Level
Observe coal flow in hoppers	YES	NO
Inspect goosenecks	YES	NO
Clean goosenecks	YES	Only remotely initiated mechanized operation
Observe charging conditions at charging holes	Only if suitable viewing system provided (mirrors)	YES
Easy access to equipment near charging holes during charging	NO	YES

The final choice of the cab location will depend on conditions at the local plant where the car will be operated. The high level cab would appear to be a safer environment for an operator. If a suitable viewing system can be provided, the HIGH level location is preferred by this writer.

Environmental Control Unit

An environmental control unit is an attractive feature for a larry car. More work is needed to develop one that does not require excessive maintenance and meets air quality standards. The worst problem with the AISI/EPA larry car unit is the large amount of maintenance required to keep it operative. The improvement of the battery environment with smokeless charging and pushing, an minimal door leakage should significantly extend the life of the unit components. A unit that will filter out particulates and regulate air temperature, requiring no more than weekly maintenance, would be a significant improvement.

Coal Feed System

The simplest system that will provide a reliable feed is

Coal Feed System (continued)

preferred. Gravity feed and forced feed systems are available. The requirements of a coal feed system have been discussed in Section VIII (page 110). The type of system that meets these requirements best for the conditions existing at a specific battery should be selected. Volumetric measuring sleeves should be provided for each hopper.

A desirable feature for a coal feed system, would be the availability to an operator of coal flow meters for each hopper. This operator's tool would enable him to take immediate remedial action when coal flow is not proper. A bottom level sensor is almost essential. It would be used to close the hopper shut-off valve and permit re-lidding.

Drop Sleeves

Drop sleeves are required to guide the coal from the hopper into the charging holes without spilling coal on the battery, and seal the oven port. The type of drop sleeve used depends on the type of coal feed system and charging system used. The specific design must incorporate features that will not adversely affect the coal flow from the hopper.

Lid Lifters

Lid lifters are a very desirable feature of a charging system. They perform a portion of the work which otherwise must be done by a Lidman. When malfunctions occur that result in flaming gases blowing out the charging holes, the mechanized operation permits instant re-lidding. Careful consideration must be given to heat sensitive components in seeing that they are properly protected.

Ascension Pipe Damper Mechanisms

A mechanized ascension pipe linkage operator that can be initiated by a push button to place an oven on-the-main, or damper-off, is a very useful operating tool, if it is reliable. The present performance of the mechanisms at P-4 battery has not reached an acceptable level of reliability as indicated in Section VIII, page 121. The reliability has not been attained

Ascension Pipe Damper Mechanisms (continued)

because the design does not yet satisfy all the necessary operating conditions. The design of such a linkage on a new battery could be improved as a result of known problems that occurred at P-4. It is believed that a reliable system can be designed and built. The improved operating and working conditions that can result from the use of mechanized ascension pipe linkages suggests that enough work should be done in this area to assure that reliable operation is achieved.

Gooseneck Cleaner

A mechanized gooseneck cleaner is a desirable operating tool that has been furnished on recent larry cars. The operating controls for these mechanisms have been at the gooseneck cleaner itself. The gooseneck cleaner for the AISI larry car went one step further by making provision for self alignment so that it could be operated remotely from within the cab. The self-aligning design has not yet been field tested, so that its reliability is not proven.

A mechanized cleaner will promote more regular cleaning of goosenecks and as such is a recommended feature on a new larry car. Its location on the larry car must be planned to minimize the larry car operating cycle, such as using it on an oven different from the one being charged, if the charging sequence will permit

Coal Bin Gate Operator

A power operated coal bin gate operator is recommended for a new larry car.

Electric and Hydraulic Power

Electric power is required for all cars. Most recent cars have utilized 460 volt a-c three-phase power. 250 volt d-c power was provided for most older cars and a few recent ones. The selection of the power supply is often a function of availability at the local plant level. Some plants prefer d-c power since constant potential control for traction drives are less complex and require less technical "know-how" to maintain.

Electric and Hydraulic Power (continued)

This writer believes that most new batteries will prefer the use of 460 VAC because:

1. It is usually more readily available.
2. Many functions utilize standard a-c motors.
3. Less difficulty in minimizing ground loops by ease of isolation.
4. Many electric and control devices more readily available in a-c.
5. Commercial a-c to d-c power conversion equipment is readily available where needed.

The use of stainless steel power supply rails are preferred because of less deterioration from the battery environment and improved contact at the collector shoe as a result of less corrosion.

Some of the larry car functions can be better performed by hydraulic power, and consequently a hydraulic system is recommended. The experience with the AISIcar indicates that sufficient reliability can be built into the system for practical usage. Where improved operating performance of sub-systems can be attained by the use of hydraulics, the equipment should be carefully selected.

Automation Hardware

Most of the equipment provided on a larry car will require some measure of automatic sequencing. The type of control equipment used external to an enclosed cab and control room must be selected with extreme care. Failure of sensors was a severe problem on the AISI/EPA larry car. They are exposed to the full range of environmental conditions from oven flames to quench tower sleet. The number of sensors used should be minimal, limited to only those necessary to reliably sequence the equipment. Consideration should be given to using on certain applicable functions, hydraulic pressure switches that can be located in an enclosed cabinet. Sensors that are required must be suited to the conditions to which they are exposed.

Automation Hardware (continued)

The sequencing control can utilize either mechanical relay logic or static logic. Static logic was originally selected for the AISI/EPA larry car because of the necessity to get all the equipment in the available space. Relays were used only to perform the necessary final output functions. An environmentally controlled atmosphere was available. The logic equipment has performed reliably.

Several factors to be considered in making a selection of sequencing control equipment are as follows:

1. Reliability
   Static logic, properly applied and installed will be more reliable. Most installations have relays for the final output. This is no longer a necessity since direct static switches such as Triacs are available.

2. Flexibility
   Changes to the control sequence can be made much more readily with static logic than with relays. If no new sensors or outputs are involved, it usually involves only minor changes in the backplane wiring. Spare logic elements are more readily available. Wiring changes to relays are more difficult to make.

3. Trouble Shooting
   An experienced technician can probably trouble-shoot static logic, furnished with status indicating lights, using a volt-ohmmeter in the same time span or less as that involving relays. Where experienced technicians are not available on a 24-hour basis, the use of relays would be favored. If the control sequencing is relatively complex, then static logic is favored if technicians are available.

4. Environment
   The coke oven environment favors the use of relays unless controlled conditions are assured. There have been no observed problems with the logic on the AISI/EPA larry car that are related to the environment. If an environmental control unit is furnished on the car, there would be no need to rule out the use of logic equipment

Automation Hardware (continued)

The use of relay logic would be preferred in most coke plants because of trouble shooting difficulties with untrained personnel and the inability to continuously maintain an controlled environment.

Automatic Sequencing

The automatic sequencing of individual operations initiated by the larryman is preferred. These operations would include:

1. Normal car travel - master switch.
2. Unidirection creep travel for gun sight spotting by pushbutton.
3. Emergency travel by pushbutton causing all equipment to move to travel position.
4. Remove or replace lids.
5. Place oven on-the-main.
6. Damper off on oven.
7. Start and stop coal feed (automatic stop when empty)
8. Clean gooseneck.
9. Coal bin gate operator.

A voice system between the pusher machine and larry car is necessary for coordination.

The use of an automatic system utilizing control signals between the pusher machine and larry car is not necessary (refer to Section VIII, page 145). A pusher machine - larry car alignment interlock, although useful, is not necessary.

PUSHER MACHINE

The worst case leveler bar duty cycle should be determined so that its design and material will satisfy the operating conditions. The automated motion of the leveler bar is recommended. This sequence would include a definite number of strokes during the final pass to assure a clear gas passage in the oven after charging.

A smoke seal must be provided that minimizes any opening around the leveler door. During operation of the leveler bar it must continuously maintain a tight fit between the leveler door opening and the smoke seal, as well as between the smoke seal and the leveler bar. A mechanized leveler door operator is desirable.

CONSIDERATIONS ON THE BATTERY

Double Gas Off-Take

A double gas off-take would be achieved on most new batteries by the selection of a double collecting main. If the experience in using jumper pipes from an extra smoke hole shows comparable overall results at less maintenance, then this approach can be considered.

Adequate Steam Aspirating System

An adequate steam aspiration system is required to direct all the gases generated or displaced during charging into the collecting main. The experience with the 693 ft^3 ovens at P-4 battery indicates satisfactory aspiration is obtained with 120 psi steam pressure applied to a 3/4" steam nozzle on a design "A" gooseneck (Figure 51), with a jumper pipe arrangement shown on Figure 31. This configuration provides a gas flow of approximately 1300 SCFM at each ascension pipe. Part of the gas flow in the second ascension pipe originates in the adjacent oven.

A steam supply pressure reducing control that permits adjustment of the steam pressure is desirable to limit the steam usage to only that amount required. The steam piping to individual ovens must be of sufficient size to assure adequate pressure at the steam nozzle. Two steam supply lines to a 4" header were provided at P-4 battery to assure adequate pressure at all ovens.

Operation of Ascension Pipe Mechanisms

The design of the gooseneck cleaner, damper, steam, and lid mechanisms must incorporate provisions to assure proper operation with the dimensional position variations that can be expected during the life of a battery. These considerations involve:

Operation of Ascension Pipe Mechanisms (continued)

1. Overall battery growth.
2. Change in standpipe position because of difference in the collecting main movement and battery growth.
3. Change in larry car position resulting from rail movement as well as normal car positioning errors.

To a lesser extent these considerations apply to the drop sleeve which, depending on the design, may have to seat within the charging hole ring.

SECTION X

APPLICATION TO EXISTING BATTERIES

The modification of an existing battery to achieve "smokeless" charging must be done with due consideration to its present operating condition. As a result of the experience gained in mechanizing the operation at P-4 battery, it is recommended that the scope of work involve no more than required to meet necessary goals in eliminating charging emissions.

DOUBLE GAS OFF-TAKE

The first consideration is to determine the method of obtaining a double gas off-take. Many existing batteries have a double gas collecting main which fulfills this requirement. For the remainder of the batteries having single collecting mains, some modification will be required. If a battery was furnished with an extra smoke hole (such as P-4 battery), then the use of jumper pipes provides a good solution.

The remaining batteries with single gas collecting mains having no spare smoke hole require special study. Among some possible considerations to be investigated are:

1. Addition of smoke hole at each oven so that either jumper pipes or a second gas collecting main could be installed.

2. Use of a jumper pipe attached to the larry car to connect one charging hole with a similar one on an adjacent oven.

ADDITION OF SMOKE HOLE

Most ovens can be modified to incorporate a smoke hole. There are a few oven designs that would make this job difficult. The age and condition of the battery would be an important consideration.

It would probably take 80-90 working days to build smoke holes into an 80 oven battery. This is based on a required time of seven working days per oven as follows:

ADDITION OF SMOKE HOLE (continued)

Days	Task
2	Cool down
1	Tear out brick
2	Rebuild
2	Heat-up and do hot work

Ovens would generally be taken out of service in groups of six or eight.

The rough estimated costs on a per-oven basis are:

Labor	$3,000
Material	500
Engr., Supv., Overhead	500
Total	$4,000
80-oven battery	$320,000

ADJACENT CHARGING HOLES

This modification has been reported in operation at several

ADJACENT CHARGING HOLES (continued)

batteries.[3, 5, 15] The jumper pipe is carried and set in place by the larry car. The end charging hole at the opposite side from the collecting main is generally used. A typical procedure is to charge that port first, then open the valve to the jumper pipe and use it for the second gas off-take. One installation charges with #1, 2 and 4 hopper only and uses the jumper pipe at #3 charging hole.[15]

Reported problems with these methods involve:

1. Improper seal between charging hole and jumper pipe.
2. Must perform frequent cleaning of the jumper pipe.
3. More work for the lidman.

ADEQUATE STEAM ASPIRATION

Many existing batteries will not have sufficient steam aspiration. A first consideration is to utilize the available steam. Since there are so many variables which determine the required steam ejection, the best approach is to make actual tests on a pair of ovens. Factors such as oven size and ascension pipe dimensions and configuration affect the required aspiration, which determines the general steam requirements. From known characteristics of similar type ovens, or extrapolating the results of published data, an approximate level of gas flow is determined. In the absence of any available data, the gas flow for any particular ascension pipe arrangement may be measured using the EMPTY OVEN TEST procedure described in Appendix E. A knowledge of the existing aspiration characteristic as shown on Figure 51 (pg. 159) can be used to estimate the new requirements.

Aside from data given in this report, steam aspirating requirements for existing batteries are available in many published papers.[3, 11, 14] It is interesting to note that measurements of an average gas evolution of 4000 SCFM during the first two minutes of charging a 1391 ft^3 oven are not quite double our estimated requirements (pg 179) of about 2200 SCFM* capacity for a 693 ft^3 oven.

* 2600 SCFM total with an estimated 400 SCFM from the adjacent oven.

ADEQUATE STEAM ASPIRATION (continued)

Using equations contained in Appendix E and curve characteristics similar to those of Figure 51, the new steam requirements can be estimated using the characteristics of the available steam pressure temperature, and nozzle configuration.

Based on the estimated steam and nozzle requirements,set up a temporary steam line to a pair of ovens and observe the results during actual charging conditions. If the second gas off-take cannot be made available for this test, then provide sufficient capacity for smokeless charging during the first 75% of the charge (prior to blocking the gas passage at the top of the oven) from one ascension pipe.

The required steam may be calculated once the requirements on an oven have been determined. A steam pressure regulating station is recommended so that optimum steam pressure may be determined after the installation is complete.

LARRY CAR REQUIREMENTS

Since existing batteries have a larry car, the first consideration is to make necessary modifications as required, provided the car is in satisfactory condition. The AISI/EPA charging system requirements that affect the larry car are:

1. Sealed oven ports
2. Controlled coal feed system
3. Sequential relidding of oven ports

Most existing cars have some type of drop sleeve, but in some cases they are all operated from one mechanism. The drop sleeves must be individually operated to permit sequential relidding.

The fit of the drop sleeve with the charging hole ring must be sufficient to form a seal. Some method is required to seal the drop sleeve open port after charging. A bottom coal level sensor can be provided to stop the coal feed at the proper time and initiate any sequence necessary to seal the port.

A coal seal may not be convenient to use on many cars.

LARRY CAR REQUIREMENTS (continued)

Some existing table feeder larry cars are being modified by using a cylindrical plug in the gas exhaust stack above the drop sleeve. This plug is lowered to seal the opening from the drop sleeve to the hopper when the level detector stops the coal feed. A slide gate arrangement can be used on some gravity feed cars.

The requirements for controlled feed are satisfied by individual hopper feed control and coal level sensors. Gravity feed or forced feed larry cars may be used. Volumetric measuring sleeves are necessary to assure each hopper of a consistent coal charge volume.

Sequential lidding of oven ports can still be done by the lidman. Some operators may wish to add automatic lid lifters to relieve the lidman of this task. The addition of lid lifters, although desirable, may be difficult, depending on the condition and design of the existing car.

PUSHER MACHINE MODIFICATIONS

Assuming the existing leveler bar is designed to handle the required duty cycle, provision should be made for a smoke boot to seal the leveler door opening.

SECTION XI

COST DATA

CAPITAL COSTS

The capital costs of the system installed at P-4 battery have been estimated by eliminating the abnormal costs of the total project which includes considerable development work. The breakdown in subparts is an estimate based primarily on information supplied by Koppers. Cost data represents 1970-1972 levels.

The costs of the larry car are shown in Table 10. Table 13 shows some automatic features that were furnished with this prototype system, that would not usually be included. Table 11 shows the costs of modifying the pusher machine, assuming the existing leveler bar can be used. Table 12 shows the costs of modifying the battery. Table 14 contains estimated costs of a new leveler bar.

INSTALLATION

The lost production during installation was very small since the larry car was installed at the extreme south end of the battery. The alignment of charging hole rings and the placement of the car positioning panels was performed for the most part with about 4 to 6 hours charging delay per oven.

Table 10. LARRY CAR CAPITAL COSTS

(1970-1972 dollars)

Component	Material Costs	Engineering Costs	Installation Labor	Total
Frame	$80,536	$38,298	$16,516	$135,350
Traction drive	48,345	12,469	8,999	69,813
Lid lifters	72,334	14,321	19,624	106,279
Damper and steam operator	11,681	3,211	12,374	27,266
Ascension pipe cleaner	7,753	29,062	8,000[a]	44,815
Feed hoppers	18,650	11,869	7,422	37,941
Butterfly valves	23,850	19,464	3,859	47,173
Level sensors	5,134	5,855	4,240	15,229[b]
Bin gate operator	8,832	8,544	4,880	22,256
Hydraulic system	24,308	6,050	5,826	36,184
Butterfly hydraulic[c]	19,800	5,000	4,720	29,520
Environmental equipment	23,607	5,284	2,130	31,021
Miscellaneous Elec. and supply[d]	44,369	4,620	15,500	64,489
Voice communication system	3,529	5,299	2,000	10,828
Electric checkout	--	--	22,000	22,000
Total	$392,728	$169,346	$138,090	$700,164

a. This anticipates labor costs.

b. Costs of using latest level sensor would probably be less than 50% this value.

c. This is cost of that part of the hydraulic system required for the butterfly valve type of gravity coal feed.

d. This includes a-c supply and collector rail system on existing collector supports. The installation labor for this item does not include supervision.

Table 11. PUSHER MACHINE CAPITAL COSTS

(1970-1972 dollars)

Component	Material Costs	Engineering Costs	Installation Labor[c]	Total
Leveler bar relocation	$2,500	$10,388	$13,546	$26,434
Leveler door oper.on 79 doors	75,268	27,058	7,761	110,087
Leveler bar seal[a]	23,420	11,314	9,193	43,927
Total	$101,188	$48,760	$30,500	$180,448[b]

a. This mechanism includes a coal chute.

b. This does not include a new leveler bar, if required.

c. Installation labor does not include supervision.

Table 12. BATTERY MODIFICATION CAPITAL COSTS

(1970-1972 dollars)

Component	Material Costs	Engineering Costs	Installation Labor [f]	Total
Steam aspiration[a]	$25,284	$3,080	$17,428	$45,792
Self cleaning steam nozzles[b]	7,290	2,215	3,000	12,505
Ascension pipe damper, lid & steam linkages	30,000	4,000	14,000	48,000
Jumper pipes	80,000	5,000	40,000[c]	125,000
Charging hole lids	8,698	585	323	9,606
Battery reinforcing[e]	10,000	2,500	6,500	19,000[d]
Total	$161,272	$17,380	$81,251	$259,903

a. Includes new steam supply lines, header, pressure regulator, piping to individual ovens, steam valves.

b. Self-cleaning steam nozzles have not yet been proven successful.

c. Anticipated labor costs.

d. Does not include reinforcement of collector rails.

e. Reinforce south end battery, remove coal bin scale and replace with steel stools, install hydraulic car bumper at south-end of battery.

f. Installation labor does not include supervision.

Table 13. CHARGING SYSTEM OPTIONS

(1970-1972 dollars)

Component	Material Costs	Engineering Costs	Installation Labor[f]	Total
Larry car position system	$12,678	$12,344[a]	$20,537[b]	$45,559
UHF alignment system	15,681	2,215	2,000	19,896
Current signal system	41,163[c]	6,643	16,567[d]	64,373
Automatic charging mode	50,000[e]	--	--	50,000
Total	$119,522	$21,202	$39,104	$179,828

a. Engineering costs include structural study and determination of proper reinforcement of collector rail supports.

b. Includes cost of reinforcing collector rail supports (about 60% of installation labor).

c. Includes control equipment in larry car, pusher machine, battery, and wayside loops.

d. Primarily cost of installing wayside loops.

e. Logic control equipment in larry car.

f. Installation labor does not include supervision.

Table 14. LEVELER BAR COSTS

Component	Material	Vendor[a] Quotation
Standard leveler bar	A-36 steel[b]	$6,700
	A-517-68 Gr.J[c]	8,800
Wedge type leveler bar	A-36 steel	8,600
	A-517-68 Gr.J	11,800

a. Quotations to Koppers, January 1974
b. Standard type steel used on existing bar
c. Recommended type steel

OPERATING AND MAINTENANCE COSTS

An evaluation of projected operating and maintenance costs related to the new charging system at P-4 battery is based on a comparison of the qualitive change of cost elements.

ENERGY REQUIREMENTS

The required aspirating steam at two ovens per charge increases the estimated steam requirements by a factor of 4.7. This increase corresponds to a steam usage of 6100 lb/hr. during charging. Based on five minutes/charge and five charges/hour, the steam requirements, neglecting leakage, are 2540 lb/hr.

The larry car has the following estimated electrical requirements.

Charging (Cycle pump loading)		30-60 KVA
	estimated average	40 KVA
Traction Drive	accelerate	120 KVA
	steady state	30-40 KVA
Car Idle (Environmental control unit)		5-10 KVA

OPERATING PERSONNEL

There has been no change in the manpower requirements to operate this battery. Three operators are required to charge coal in the ovens.

1) charging car operator
2) pusherman
3) lidman

MAINTENANCE PERSONNEL

The required maintenance on the larry car is shown on Table 15. Additional maintenance requirements related to charging are shown on Table 16. The estimated maintenance requirements are based on data taken over a three month period (December 1973 - February, 1974). The estimated requirements account for the fact that the car was in use slightly less than half the time and also reflect expected improved performance of hydraulic equipment. The estimated 79 manhours per week of millwright, oiler, and electrician maintenance service is believed to be double the previous repair work used on the P-3 larry car. The maintenance

Table 15. LARRY CAR MAINTENANCE REQUIREMENTS

Component	Craft[a]	Weekly Maintenance Man-hour Requirements	
		Preventative Maintenance	Breakdown Repairs
Hydraulic system	Millwright		
Main hydraulic unit		2	
Hydraulic leaks		4	4
Hydraulic hoses		4	4
		10	8
Mechanical equipment	Millwright	3	6
Lubrication	Oiler	10	
		13	6
Environmental control unit	Millwright		
Change throw-away filter		2	
Clean Louvers, change bag filter		2	
General maintenance		2	
		6	0
Electrical system	Electrician		
Clean equipment, check filters, check for grounds		6	
Replace damaged equip.		6	8
		41	22

a. Millwrights work in pairs - break-down hours are 1/2 man-hour. Electrician usually works singly - break-down hours equal man-hour.

Table 16. OTHER CHARGING MAINTENANCE REQUIREMENTS

Component	Craft	Repair and Maintenance (man-hr.)
Pusher machine		
Door opener	Millwright	3
Leveler bar, smoke shield	Millwright	1
Electrical	Electrician	2
Ascension pipes		
Damper - lubricate	Oiler	2
Damper and lid linkages	Millwright	4
Steam linkages	Millwright	4
		16
Jumper pipes (weekly clean-out)	Lidman	14
		30

MAINTENANCE PERSONNEL (continued)

requirements have increased 40 man-hours. This does not include estimates for increased supervision. The greater complexity of the hydraulic and electrical systems necessitate the availability of qualified supervisory personnel. The increased supervision time is in the range of 12-16 man-hours per week divided equally between electrical and mechanical-hydraulic.

The efficient operation of this battery,as related to the present practices of Pittsburgh Works, requires that equipment be available for satisfactory production use about 95% of the scheduled time. This assumes a given piece of production apparatus will be scheduled for eight hours maintenance per week and that for the remaining 20 turns, it will be available for operation 152 hours.

The data in Table 15 indicates that the scheduled maintenance can be done in eight hours with an average of two millwrights and 1 1/2 electricians. The average breakdown time is almost 16 hours which corresponds to 90% availability of the larry car.

The future addition of jumper pipes and improved reliability in the coal feed system are expected to improve the car reliability. The average larry car availability under these conditions is expected to be about 95%.

SECTION XII

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SECTION XIII

GLOSSARY

Charge Cycle Time - Time interval from start of coal charge (first butterfly valve opens) till re-lidding complete (all charging hole lids in place).

Charging On-The-Main - Opening the damper valve to connect an oven with the gas collecting main through an ascension pipe, and with fluid ejectors turned on to draw charging emissions into the collecting main.

Charge Time - Time interval from start of coal charge till final coal feed (last butterfly valve closed).

Oven Ports - Oven openings consisting of the charging holes, leveler door, and the ascension pipe elbow cover.

T_0 - Number of seconds of no smoke during charging.

T_1 - Number of seconds in which smoke opacity is less than 20% (Ringelmann #1), but greater than T_0.

T_2 - Number of seconds in which smoke opacity is less than 40% (Ringelmann #2) but greater than T_1.

T_3 - Number of seconds in which smoke opacity is equal or greater than 40% (Ringelmann #2)

PB - Pushbutton

Smokeless Charging - Any and all emissions from oven ports less than 20% opacity during the entire charge cycle time. Opacity readings are determined at the source.

GLOSSARY (continued)

w.c. - Water column - a measure of relative gas pressure in terms of a differential water column heighth in a U-tube manometer referenced to atmospheric pressure.

SECTION XIV

CONVERSION FACTORS

Environmental Protection Agency policy is to express all measurements in agency documents in metric units. When implementing this practice will result in undue cost or lack of clarity, conversion factors are provided for the non-metric units used in a report. Generally, this report uses British units of measure. For conversion to the metric system, use the following conversions:

To Convert from	To	Multiply by
Btu/lb-F	J/kg-C	4184.
Btu/min	W	17.573
Btu/ton	J/kg	2324.444
cfm	m^3/sec	.0004719
°F	°C	5/9 (°F-32)
ft	m	.3048
gal.	l	3.785
gpm	l/sec	0.0631
hp	W	745.7
in.wc	N/m^2	248.84
lb	kg	0.454
lb/ft^3	kg/m^3	16.018
oz	N/m^2	430.922
psig	N/m^2	6,894.757

SECTION XV

APPENDICES

A. Oven Pressure Measurements 202

B. Reliability Data 204

C. Leveler Bar Investigation 224

D. Emission Data 261

E. Empty Oven Tests 283

F. Battery Dimensional Variations 291

G. Ascension Pipe Particulate Sampling 295

APPENDIX A

OVEN PRESSURE MEASUREMENTS

Measurements of the oven pressure during charging were made at the smoke hole (located on coke side of oven - Figure 1) by J. R. Lee. A pressure recorder was mounted on the larry car, and pressure tubing was connected to a test lid with a small hole drilled in the center. The test lid was placed on the smoke hole and sealed with asbestos rope and mud. The pressure in the oven at the smoke hole was then recorded throughout the charge. Eight pressure recordings were made from May 25, 1973 to June 15, 1973. The results verify that the efforts to prevent blockage of the gas passage have not been adequate. In every charge the pressure increased significantly when the leveler bar was used during the coal feed. The maximum pressure at the smoke box during leveling averaged 8.5 inches of water column (max. - maximum 13 inches, min-maximum 3 inches). This compares with an average maximum pressure of 1 inch of water column (max. - maximum 4 inches, min-maximum 1/2 inches) during the 75% charge prior to leveling.

Also observed in these tests, is that the longer that the 1st 75% of the coal charge is leveled before the final 25% is started, the longer it takes for the coal blockage in the gas passage to occur.

Date	Oven No.	Duration of Leveling Before Final 25%	Time Until 1st Coal Blockage
5/31/73	2-17	4 seconds	0 seconds
6/31/73	2-17	12 seconds	0 seconds
5/30/73	2-24	15 seconds	12 seconds
5/25/73	3-3	33 seconds	15 seconds
5/31/73	2-19	34 seconds	16 seconds
5/31/73	2-15	45 seconds	12 seconds
5/31/73	2-15	45 seconds	18 seconds
5/31/73	2-21	180 seconds	21 seconds

A copy of a pressure recording taken on oven 2-19 on 5/31/73 is shown on Figure 54.

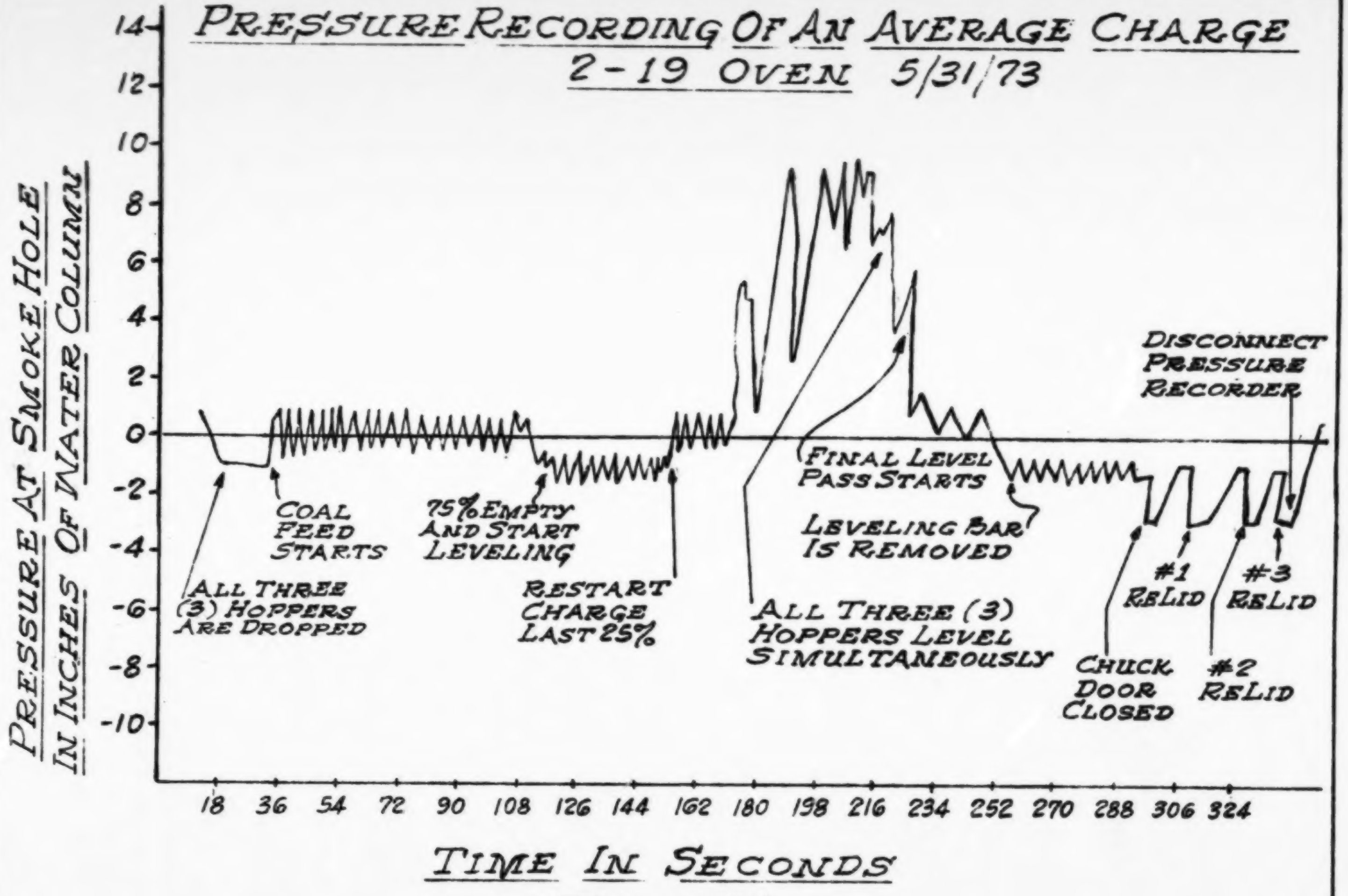

PRESSURE RECORDING OF AN AVERAGE CHARGE
2-19 OVEN 5/31/73
PRESSURE AT SMOKE HOLE IN INCHES OF WATER COLUMN
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
TIME IN SECONDS
18
36
54
72
90
108
126
144
162
180
198
216
234
252
270
288
306
324
ALL THREE (3) HOPPERS ARE DROPPED
COAL FEED STARTS
75% EMPTY AND START LEVELING
RESTART CHARGE LAST 25%
ALL THREE (3) HOPPERS LEVEL SIMULTANEOUSLY
FINAL LEVEL PASS STARTS
LEVELING BAR IS REMOVED
CHUCK DOOR CLOSED
#1 RELID
#2 RELID
#3 RELID
DISCONNECT PRESSURE RECORDER

Figure 54

APPENDIX B

LARRY CAR RELIABILITY DATA

CRITERIA

The criteria used to determine minimum acceptable larry car performance are:

1. The car and associated charging equipment are available for satisfactory production operation 90% of the total operating time.

2. The required scheduled maintenance shall not exceed a total of eight hours during any one week period.

LARRY CAR AVAILABILITY

The quantitative evaluation of this criteria in terms of larry car availability is determined from the following relation, defined in Figure 55.

$$A = \frac{P}{n} \times 100 \qquad (1)$$

This measure of larry car reliability is essentially the ratio of actual charging time to the total scheduled time that the car could be used for production charging. The difference between "p" and "n" represents the normal time required for making breakdown repairs and the extra maintenance requirements that exceed the 8 hour/week rate.

OPERATING PROBLEMS

The available charging time "n" does not include lack of production use because of operating problems not associated directly with the car reliability.

The nature of the operating problems which prevent the use of the new larry car during charging can best be understood by referring to Figure 57 (page 206) which shows the location of the coal bin and the larry cars used at P-4 battery. When the new P-5 larry car is used to charge ovens on P-4 battery, the old spare P-4 larry car is parked at the center of the coal bin. The P-3 larry car then uses the north side of the coal bin to get coal for charging P-3 battery, and the P-5 larry car uses the south end of the coal bin to get coal for charging P-4 battery.

If P-3 larry car breaks down and requires repairs it must be parked in the center of the coal bin. It is then necessary to use P-2 larry car to charge P-3 battery and P-4 larry car to charge P-4 battery. Under these conditions, which will not exist when P-4 car is dismantled, it is necessary to take P-5 car out of service.

Another temporary operating condition which requires taking the P-5 car out of service occurs when the south end of the coal bin is empty and it becomes necessary to get coal near the center. It is then necessary to use P-4 car to charge ovens on P-4 battery.

Occasionally P-5 car is not used if a trained operator is not available to run the car on any particular turn. This usually occurs if the regular operator reports-off sick, and the back-up man does not have sufficient training.

It has become necessary to clean the goosenecks and return bends of the gas off-takes on a weekly basis over and above that done by the operator during charging. The man doing the cleaning stands on a platform so that he can use a bar to clean out through the ascension pipe inspection port. The clearance between this platform and the new P-5 larry car is very small (less than 1") while that with the P-4 car is almost 12". Consequently when this work is performed, the spare P-4 larry car is used for charging in order to realize the necessary safety condition for a man performing the cleaning. This procedure should not be necessary when the mechanized gooseneck cleaner is operational.

AVAILABLE PRODUCTION CHARGING TIME

The available time for production charging with the new P-5 larry car is defined in Figure 55 as

$$n = t - (b + m_1 + m_p + f + w_2). \qquad (2)$$

Definition of Larry Car Availability and Utilization

$$A = \frac{p}{n} \times 100 \qquad (1)$$

$$n = t - (b + m_1 + m_p + f + w_2) \qquad (2)$$

$$p = n - (r + m_2 + w_1) \qquad (3)$$

$$U = \frac{n}{t} \times 100 \qquad (4)$$

where A = larry car availability for production operation, per cent

p = actual time used for production charging, hours.

n = available time for production charging with this larry car, hours.

t = total scheduled time for charging P-4 battery (normally 24 hours/day), hours.

b = time not available for charging with this larry car because of operating problems not associated with this charging system reliability, hours.

m_1 = time utilized for scheduled maintenance that is less or equal to a limit of 8 hours/week, hours.

m_2 = maintenance time utilized which exceeded the allowable 8 hours/week scheduled maintenance, hours.

m_p = time utilized to perform design modification work on the larry car, hours.

f = time the car is not used for production charging, but is in operating condition. This is specifically the elapsed time from completion of repair work until the larry car is placed in service, hours.

w_1 = normal time waiting for repair craft to start repair work, hours. This assumes no other larry car is available to charge P-4 battery.

Figure 55

Definition of Larry Car Availability and Utilization

(continued)

w_2 = time waiting for repair craft to start repair work, hours. This assumes that a spare car is available and the craft delay repair work because there are higher priority tasks to be completed first.

r = actual time required for repairs, hours.

U = larry car utilization, per cent. This represents the time available to charge with the new larry car compared with the total time period.

Figure 55

AVAILABLE PRODUCTION CHARGING TIME (continued)

In addition to the unavailable time because of operating problems, b, maintenance time that is either within the maximum 8 hour/week rate or that is of a project nature, such as design modifications, is also excluded.

Two other factors are recognized that relate to the availability of the spare P-4 larry car. If a failure occurs with the new P-5 car, it is parked at the south end of P-4 battery for repairs and the spare car is used for charging. Since no production is being lost, the required repair personnel may work on more pressing repairs elsewhere that may be affecting production. The resulting interval, w_2, between the time of failure and the time repair work starts, is not included as part of "n".

After completion of repair work, it may not be convenient to remove the spare car from production charging and place the new car in service. This elapsed time, f, occurs only because there is a spare car, and is not considered as part of "n".

ACTUAL PRODUCTION CHARGING TIME

The actual production charging time "p" differs from the available charging time "n" as given by the relation in Figure 55.

$$p = n - (r + m_2 + w_1) \qquad (3)$$

The normal delay time, w_1, represents a delay in starting repair work because the required craft is not immediately available under the assumption of no spare larry car.

LARRY CAR UTILIZATION

Because of the temporary existance of an extra spare P-4 larry car, the new P-5 car is not utilized to its maximum capability. The significance of the larry car availability, A, is weighted by the amount of utilization as defined in Figure 55.

$$U = \frac{n}{t} \times 100 \qquad (4)$$

LARRY CAR PRODUCTION INDEX

The larry car production index relates the number of charges made to the charging times used in calculating availability, as indicated in Figure 56.

$$P.I. = \frac{P}{T - (B + M_1 + M_p + F + W_2)} \times 100 \quad (5)$$

This value should be similar to the value given for availability. If there was no extra spare larry car available, the P.I. factor would be expected to be greater than, A, because some repair time can be permitted without losing production.

MAINTENANCE AND REPAIR REQUIREMENTS

A daily record was maintained of all the maintenance and repair problems with the required man hours by craft. This work has three classifications:

1. Breakdown repairs
2. Scheduled maintenance repairs
3. Design modifications (project work)

METHOD OF OBTAINING DATA

The battery turn foreman maintains a performance record for each turn on a special form shown in Figure 58. A project engineer reviews the record, clarifies data with the production personnel, and tabulates it on the daily summary sheet shown in Figure 59.

ANALYSIS OF RELIABILITY DATA

The determination of larry car performance was calculated from the daily performance data form shown in Figure 59. The summary figures for the month of January are shown. A graphical relation is shown in Figure 60. The larry car was available for satisfactory production operation 86.0% of the time which compares with the minimum criteria of 90%. A summary of the type of failures and the required man hours to perform the associated breakdown repairs or scheduled maintenance is shown on a monthly basis in Tables 17, 18 and 18a. The data for January is further detailed in

Table 19	Larry Car Failures
Table 20	Larry Car Maintenance

Table 21 Operating Problems Preventing Use of Larry Car

This data does not account directly for problems with charging wet coal which lengthens the charging time and makes it more difficult to maintain the production schedule.

Since the trend in car availability is still improving, it is believed that an upper limit is about 90%. After the addition of jumper pipes, and an improved coal feed system, it is believed that this figure will be close to 95%.

Definition of Larry Car Production Index Factor

$$P.I. = \frac{P}{T - (B + M_1 + M_p + F + W_2)} \times 100 \quad (5)$$

where P.I. = larry car production index factor, per cent. This represents the ratio of production charges made with respect to the number of charges that could have been made when the larry car was available for charging.

P = number of production charges.

T = total number of scheduled charges (full production potential).

B = charges not made with this larry car because of operating problems not associated with this charging system reliability. The nature of these problems are discussed later in this section.

M_1 = charges not made during time, m_1, that the car was out of service for scheduled maintenance up to the maximum limit of 8 hours/week. Refer to previous definition of "m_1".

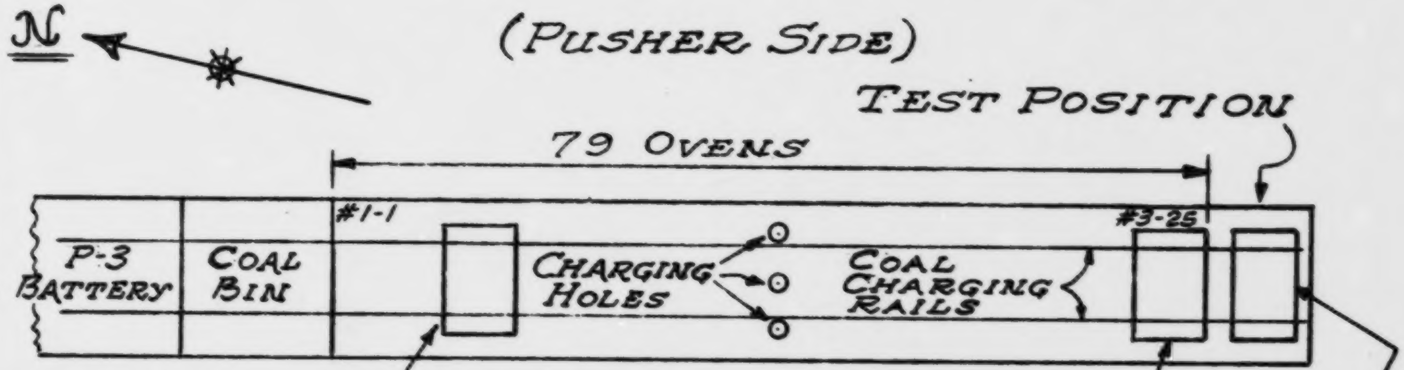
M_p = charges not made during time, m_p. Refer to previous definition of "m_p".

F = charges not made during time, f. Refer to previous definition of "f".

W_2 = charges not made during time w_2. Refer to previous definition of "w_2".

Figure 56

LARRY CARS ON P-4 BATTERY


N
(PUSHER SIDE)
TEST POSITION
79 OVENS
#1-1
#3-25
P-3 BATTERY
COAL BIN
CHARGING HOLES
COAL CHARGING RAILS
(COKE SIDE)

P-3 COAL CHARGING CAR NORMALLY CHARGED P-4 BATTERY BEFORE THE EXISTENCE OF THE NEW P-5 CAR.

EXISTING P-4 COAL CHARGING CAR IS NOW PARKED OVER SOME OVENS.

LOCATION OF NEW P-5 COAL CHARGING CAR.

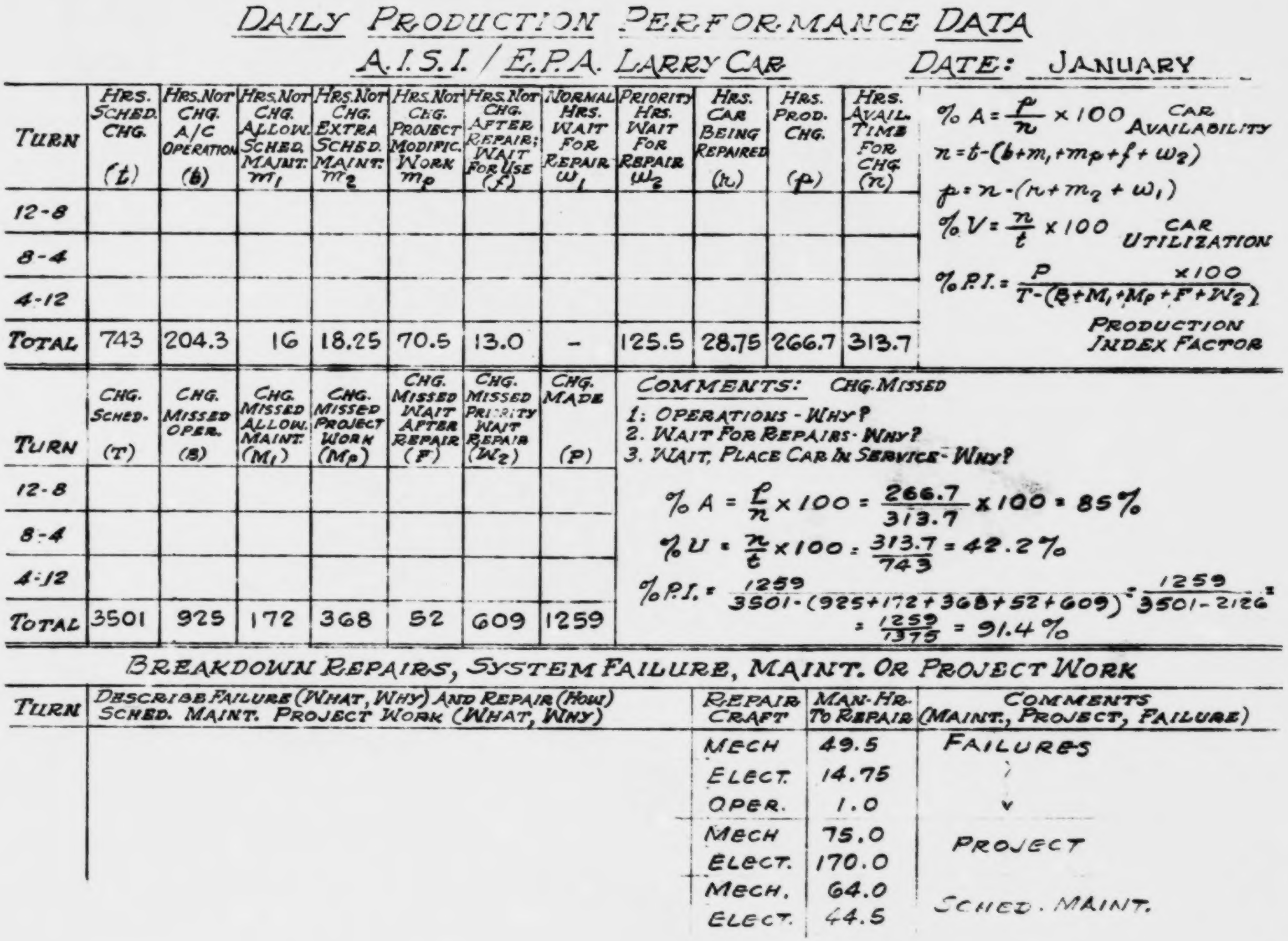
P-4 CAR WAS THE SPARE LARRY CAR FOR FIVE BATTERIES FUNCTIONING IN THREE OPERATING UNITS. P-4 CAR WILL BE DISMANTLED WHEN THE DEMONSTRATION PROJECT IS COMPLETE.

Figure 57

A.I.S.I COAL CHARGING SYSTEM - DAILY REPORT - 2-2-74

DATE	TURN	TARGET Nº OVENS TO BE CHARGED	OVENS ACTUALLY CHARGED WITH NEW CAR	IF TARGET CHARGES NOT ACHIEVED - WHY NOT?	FAILURES				
					TIME OF FAILURE	TIME OUT OF SERVICE	REPAIR TIME	REPAIR MAN HOUR	WHAT FAILED; WHY; HOW; WHAT REPAIRS REQUIRED.
2-1	3	38	38						
2-2	1	38	32	Nº1 LID LIFTER RETRACTED POSITION LIMIT SW. REPLACED, PUT IN SERVICE AT 2:45 A.M.	1:20 A.M	1:20 A.M	1 HR. & 25 MIN.		
2-2	2	38	38	-	-	-	-	-	-
2-2	3	40	10	① BROKEN HYDRAULIC HOSE DAMPER ARM (ON THE MAIN) ② NO MERCURY LIGHTS ③ OUT OF COAL ④ Nº1 HOPPER MT. LIGHT COMING ON PREMATURELY	5:30 & 9:55	5:30 - 8:30 9:55 - 12:00	½ HR.		REPLACE BROKEN HOSE REPLACE FUSE
2-3	1	38	0	MAN CLEANING RETURN BEND					
2-3	2	38	0	CLEANING RETURN BENDS	-	-	-	-	-

Figure 58



DAILY PRODUCTION PERFORMANCE DATA

A.I.S.I. / E.P.A. LARRY CAR DATE: JANUARY

TURN	HRS. SCHED. CHG. (t)	HRS. NOT CHG. A/C OPERATION (b)	HRS. NOT CHG. ALLOW. SCHED. MAINT. m_1	HRS. NOT CHG. EXTRA SCHED. MAINT. m_2	HRS. NOT CHG. PROJECT MODIFIC. WORK m_p	HRS. NOT CHG. AFTER REPAIR; WAIT FOR USE (f)	NORMAL HRS. WAIT FOR REPAIR w_1	PRIORITY HRS. WAIT FOR REPAIR w_2	HRS. CAR BEING REPAIRED (r)	HRS. PROD. CHG. (p)	HRS. AVAIL. TIME FOR CHG (n)
12-8											
8-4											
4-12											
TOTAL	743	204.3	16	18.25	70.5	13.0	-	125.5	28.75	266.7	313.7

$\% A = \frac{p}{n} \times 100$ CAR AVAILABILITY

$n = t - (b + m_1 + m_p + f + w_2)$

$p = n - (r + m_2 + w_1)$

$\% V = \frac{n}{t} \times 100$ CAR UTILIZATION

$\% P.I. = \frac{P}{T - (B + M_1 + M_p + F + W_2)} \times 100$

PRODUCTION INDEX FACTOR

TURN	CHG. SCHED. (T)	CHG. MISSED OPER. (B)	CHG. MISSED ALLOW. MAINT. (M_1)	CHG. MISSED PROJECT WORK (M_p)	CHG. MISSED WAIT AFTER REPAIR (F)	CHG. MISSED PRIORITY WAIT REPAIR (W_2)	CHG. MADE (P)
12-8							
8-4							
4-12							
TOTAL	3501	925	172	368	52	609	1259

COMMENTS: CHG. MISSED

1: OPERATIONS - WHY?
2. WAIT FOR REPAIRS - WHY?
3. WAIT, PLACE CAR IN SERVICE - WHY?

$$\% A = \frac{p}{n} \times 100 = \frac{266.7}{313.7} \times 100 = 85\%$$

$$\% U = \frac{n}{t} \times 100 = \frac{313.7}{743} = 42.2\%$$

$$\% P.I. = \frac{1259}{3501 - (925 + 172 + 368 + 52 + 609)} = \frac{1259}{3501 - 2126} = \frac{1259}{1375} = 91.4\%$$

BREAKDOWN REPAIRS, SYSTEM FAILURE, MAINT. OR PROJECT WORK

TURN	DESCRIBE FAILURE (WHAT, WHY) AND REPAIR (HOW) SCHED. MAINT. PROJECT WORK (WHAT, WHY)	REPAIR CRAFT	MAN-HR. TO REPAIR	COMMENTS (MAINT., PROJECT, FAILURE)
		MECH	49.5	FAILURES
		ELECT.	14.75	
		OPER.	1.0	↓
		MECH	75.0	PROJECT
		ELECT.	170.0	
		MECH.	64.0	SCHED. MAINT.
		ELECT.	44.5	

FIGURE 59

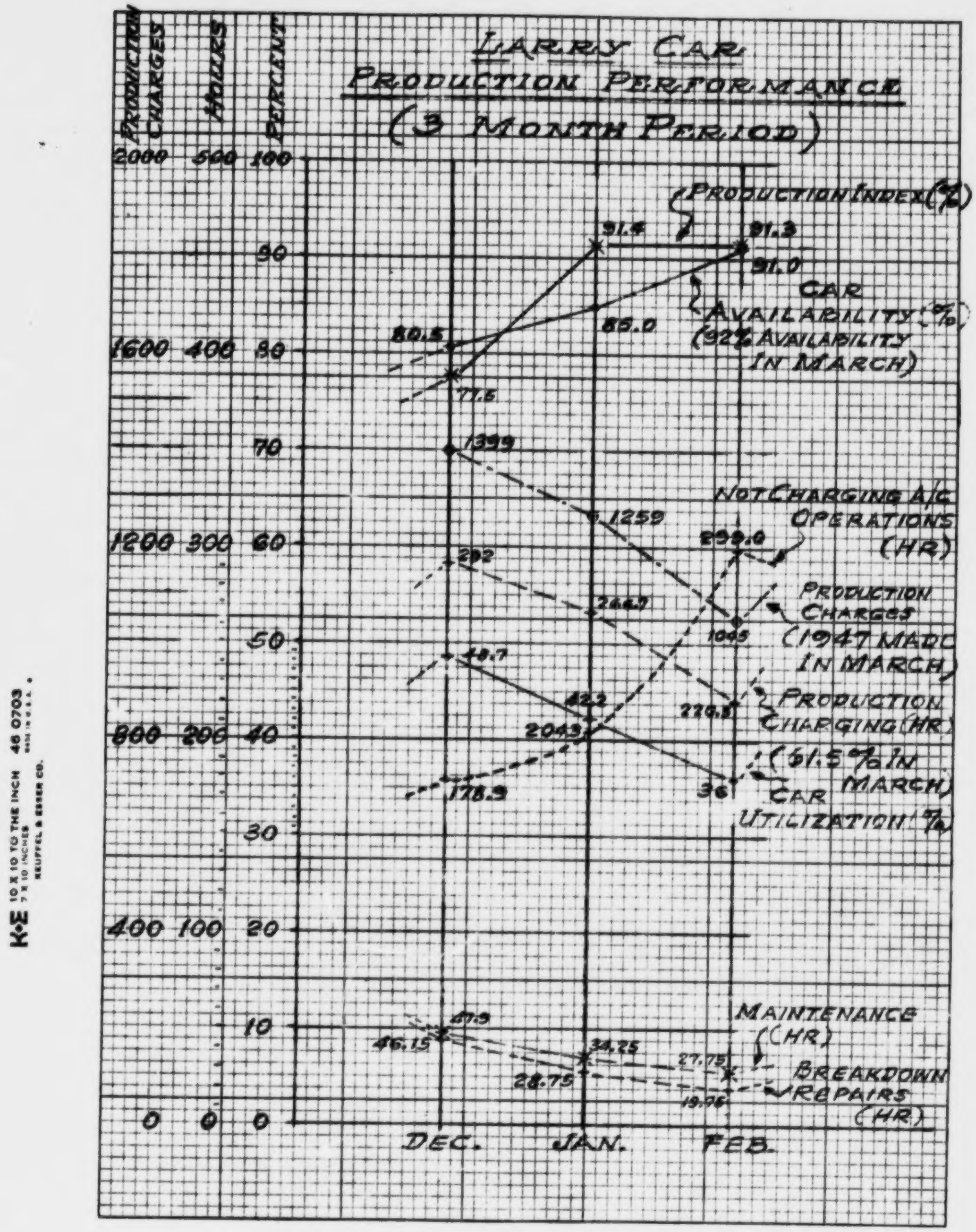

LARRY CAR
PRODUCTION PERFORMANCE
(3 MONTH PERIOD)
PRODUCTION CHARGES
HOURS
PERCENT
2000 500 100
90
1600 400 80
70
1200 300 60
50
800 200 40
30
400 100 20
10
0 0 0
DEC.
JAN.
FEB.
PRODUCTION INDEX (%)
91.4
91.3
91.0
CAR AVAILABILITY (%)
(92% AVAILABILITY IN MARCH)
85.0
80.5
77.5
1399
1259
1045
NOT CHARGING A/C OPERATIONS (HR)
299.0
292
266.7
276.5
PRODUCTION CHARGES (1947 MADE IN MARCH)
PRODUCTION CHARGING (HR)
48.7
42.2
204.3
178.9
36
(61.5% IN MARCH)
CAR UTILIZATION %
MAINTENANCE (HR)
BREAKDOWN REPAIRS (HR)
47.9
46.15
34.25
28.75
27.75
19.75
K+E 10 X 10 TO THE INCH 46 0703
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 60

Table 17. TYPE OF LARRY CAR FAILURES AND REPAIRS

DECEMBER 1973

Item	Type of Failure & Repair	Repair Man.Hr.	Maint. Man.Hr.	Total Man.Hr.
1	Hydraulic leaks and hoses[a]	25.0	36.8	61.8
2	Hydraulic actuators[b]	--	--	0.0
3	Miscellaneous hydraulic	4.0	18.0	22.0
4	Damaged mechanical equip.	--	32.0	32.0
5	Environmental control unit	--	24.0	24.0
6	Defective or grounded wiring	17.65	6.8	24.45
7	Failure, repair, adjust sensor	6.25	18.0	24.25
8	Hopper vibrator	--	--	0.0
9	Electrical problems in control room	--	--	0.0
10	Miscellaneous electrical	15.5	6.0	21.5
11	Butterfly jammed[c]	0.25	--	0.25
	Total	68.65	141.6	210.25

a. Does not include leaking or broken hydraulic actuators.
b Leaking or mechanically damaged.
c. Operator normally frees the butterfly.

Table 18. TYPE OF LARRY CAR FAILURES AND REPAIRS

JANUARY 1974

Item	Type of Failure and Repair	Repair Man.Hr.	Maint. Man.Hr.	Total Man.Hr.
1	Hydraulic leaks and hoses[a]	8.0	11.5	19.5
2	Hydraulic actuators[b]	31.5	14.0	45.5
3	Miscellaneous hydraulic	4.0	--	4.0
4	Damaged mechanical equip.	5.0	23.0	28.0
5	Environmental control unit	--	15.5	15.5
6	Defective or grounded wiring	1.5	26.0	27.5
7	Failure,repair,adjust sensor	2.0	5.5	7.5
8	Hopper vibrator	11.25	--	11.25
9	Electrical problems in control room	--	--	0.0
10	Miscellaneous electrical	0.25	13.0	13.25
11	Butterfly jammed[c]	0.75	--	0.75
	Total	64.25	108.5	172.75

a. Does not include leaking or broken hydraulic actuators.
b. Leaking or mechanically damaged.
c. Operator normally frees the butterfly.

Table 18a. TYPE OF LARRY CAR FAILURES AND REPAIRS

February 1973

Item	Type of Failure & Repair	Repair Man-Hr.	Maint. Man-Hr.	Total Man-Hr.
1	Hydraulic leaks and hoses[a]	2.0	--	2.0
2	Hydraulic actuators[b]	17.0	2.0	19.0
3	Miscellaneous hydraulic	4.0	15.0	19.0
4	Damaged mech. equipment	8.0	2.0	10.0
5	Environment control unit	--	3.0	3.0
6	Defective or grounded wiring	5.50	7.0	12.5
7	Failure,repair,adjust sensor	5.25	--	5.25
8	Hopper Vibrator	1.50	--	1.5
9	Electrical problems in control room	4.50	--	4.5
10	Miscellaneous electric	11.25	3.0	14.25
11	Butterfly jammed[c]	0.50	--	0.5
	Total	59.5	32.0	91.5

a. Does not include leaking or broken hydraulic actuators

b. Leaking or mechanically damaged

c. Operator normally frees the butterfly

Table 19. LARRY CAR FAILURES

JANUARY 1974

Item	Date	Turn	Description of Failure	Repair Craft	Repair Man.Hr.
1	2	12-8	#1 Butterfly jammed with coal, manually freed	Oper.	0.25
2	2	4-12	460 VAC breaker opened, adjusted pressure switch (#2 lid lifter dn) adjusted limit arm (#1 lid lifter extend)	Elec.	0.50
3	4	12-8	460 VAC breaker opened	Elec.	0.25
4	6	4-12	Adjusted pressure switch #2 lid lifter down	Oper.	0.25
5	11	12-8	#3 butterfly jammed, manually freed	Oper.	0.50
6	11	4-12	Pin sheared on #3 butterfly actuator, looking for trouble	Mech.	1.0
7	14	8-4	Removed #2 butterfly actuator,took to shop to make new pin	Mach.	14.0
8	15	8-4	Replaced Pin in #2 lid lifter extend cylinder	Mech.	2.0
9	17	12-8	Fuses blew twice in #1 vibrator- ran car without	Elec.	0.25
	17	8-4	Looked for trouble with vibrator	Elec.	3.0
10	18	8-4	Replace #1 vibrator	Elec.	8.0
11	19	8-4	Removed broken pipe and rethreaded	Mech.	1.5
12	19	4-12	Replcaed 20 gal.of hydarulic fluid	Mech.	4
13	21	8-4	Anchor block came loose causing #2 actuator to move and break pipe	Mech.	7.5
14	23	8-4	Replace broken hose, #2 hopper, replaced leaky hoses #3 butterfly,replaced #2 actuator with spare (mounting bolts sheared)	Mech.	12

Table 19. LARRY CAR FAILURES

JANUARY 1974
(Continued)

Item	Date	Turn	Description of Failure	Repair Craft	Repair Man.Hr.
15	25	4-12	Lubricated and adjusted #1 lid lifter limit side arm adjusted pressure switch #2 lid lifter	Elec.	0.5
16	27	12-8	Repaired ground to #2 lid lifter magnet	Elec.	1.0
17	27	8-4	Replaced leaky hose #2 butterfly	Mech.	2.0
18	28	8-4	Replaced fuse #3 hopper, straightened #1 hopper level probe	Elec.	0.25
19	28	8-4	Replaced leaking hose #3 butterfly	Mech.	0.50
20	30	8-4	Replaced #1 retract limit	Elec.	1.0
21	30	8-4	Removed damper arm, straightened, and replaced	Mech.	5.0

Table 20. LARRY CAR MAINTENANCE

JANUARY 1974

Item	Date	Turn	Description of Scheduled Maintenance	Work Craft	Work Man.Hr.
1	3	8-4	Oscillating arms straightened #1 lid lifter Replaced two hydraulic hoses (#2 butterfly, #3 lid lifter)	Mech.	16
2	3	8-4	Replaced 3 worn shoes on trolley poles, exercised and lubricated remaining shoes	Elec.	8
3	4	8-4	Removed, cleaned louvers on environmental unit, renewed flexible hose on exhaust blower (louvers)	Mech.	15.5
4	4	8-4 4-12	Found ground in 440 volt junction box of car, also partial ground in safety switch at coal bin	Elec. Elec.	16 4
5	8	8-4	Tried to remove pin from leaking #2 lid lifter extend cylinder - had to re-assemble;could not free	Mech.	7
6	8	8-4	Repair sticking limit on #3 lid lifter (contact lid) and replaced bent side arm limit on #2 lid lifter retract	Elec.	3.5
7	9	8-4	Replace #2 lid lifter extend piston and #1 lid lifter raise piston (leaky); removed and blew out clogged charcoal filters in environmental control unit	Mech.	14
8	9	8-4	Replaced junction box covers #2 lid lifter, adjusted #1 butterfly clockwise limit	Elect.	7
9	11	8-4	Tighten loose nipple on #2 butterfly; Replace leaky tubing with pipe nipples (#1 & 2 lid lifters), welded nipples to lid lifter frame	Mech.	11.5

Table 20. LARRY CAR MAINTENANCE

JANUARY 1974
(Continued)

Item	Date	Turn	Description of Scheduled Maintenance	Work Craft	Work Man.Hr.
10	11	8-4	Replaced old wire to #1 vibrator with Micamat wire	Elec.	6

Table 21. OPERATING PROBLEMS PREVENTING USE OF LARRY CAR

JANUARY 1974

Item	Type of Operating Problem	Hours Spare Car Used
1	No coal at south end of coal bin	53.45
2	Foreman elected to use spare car	46.85
3	#3 larry car being repaired at coal bin	11.0
4	No trained operator	31.6
5	Clean standpipes	61.4
		204.3

APPENDIX C

LEVELER BAR INVESTIGATION

REPORT BY L. S. POPE, J&L RESEARCH

Two coke oven leveler bars failed in service at Pittsburgh Works P-4 Coke Oven Battery during the installation program of the AISI coal charging system. These two bars were of new and different designs (open web and solid web) developed by Koppers Company. Both bars had been in service less than a month before failure occurred.

Failure occurred when the bars became distorted in the vertical direction such that they could no longer fit through the chuck doors in the coke ovens. The open web bar (design number PF3724 Revision 5) displayed a rise of about 6 1/4 inches in the first 20 feet of bar starting at the nose while the solid web bar (design number PF3724 Revision 11) displayed a rise of about 8 1/8 inches in the first 23 feet back of its nose* (see Figure 48). Furthermore, the open web bar has buckled in the upper section about 10 feet from the nose (see Figure 46). No cracks or mechanical defects were observed in either bar.

During normal operations these bars were used to level the coal being charged into a coke oven. They normally extended about forty feet into the oven and oscillated on about a 20 feet throw. During such operation, the bars were either unsupported for the entire length extended into the oven or supported by coal at points 8 feet, 21 ft. or 35 ft. from the oven door by the coal it was leveling. These particular locations were the positions of the chuck holes through which coal was charged and under which conical piles of coal developed. It was these piles that the bars leveled.

* These measurements were supplied by Karl Kortlandt of Development Engineering.

When bar failure occurred, the solid web bar had suffered an unusually long exposure** in the interior of an oven. The normal exposure time is 2 to 3 minutes, but because of difficulties in charging, the bar was in the oven about eight minutes. At the next oven to be leveled the bar just barely cleared the roof upon entering; normally, the clearance is about 3". This leveling operation was normal with a 3 minute exposure and the bar was retracted with no difficulty. At the next oven, however, the bar could not be inserted because it had acquired an upward set as described previously.

With regard the open web bar there was no available failure history other than it had failed after less than a month in service, and in significantly less time than the solid web bar.

MICROEXAMINATION

Specimens for metallographic examination were obtained from various locations in each bar. The examination revealed that the microstructure in all areas was about the same and typical of as hot rolled plain carbon structural steel, i.e. equiaxed ferrite grain size of ASTM #8 with about 15% pearlite (see Figure 61). No evidence was uncovered to indicate that the bars were overheated (heated above 1350°F) in the oven. The inclusion morphology in each case indicated the rolling direction of the original sections was along the length of the bars.

CHEMICAL ANALYSIS

Chemical analyses were also performed on both bars and the results are presented in Table 22. The analyses for all sections were similar and conformed to the specifications of ASTM A-36 structural steel. The absence of significant amounts of aluminum indicated that this steel was probably silicon semi-killed.

** Such exposure times only occurred infrequently when charging the first eight ovens of the battery which, because of construction, were charged with an inferior spare larry car.

MECHANICAL TESTING

Tensile tests were performed on specimens obtained from the web of the open web bar in the region where buckling occurred (top and bottom sections).* Both tests conformed to the tensile specifications of ASTM A-36 structural steel although there were slight differences in the strength properties of the two areas (Table 23).

DISCUSSION

There were no metallurgical defects or irregularities in the steel of either bar. Both materials were typical of hot rolled plain carbon steel and met all the specifications of ASTM A-36 structural steel. Microexamination revealed no evidence to indicate that the bars had been subjected to any unusual thermal cycles involving temperatures above 1350°F. However, because this type of microstructure is not reflective of low temperature thermal treatment we could not speculate as to any thermal cycle experienced below 1350°F.

The failure of these bars is believed to be due to a thermal expansion effect resulting from non-uniform heating of the bars while they were at least partially supported by coal in the oven. For both bars, four actual thermal - mechanical situations were possible as indicated below.

(1) If the bars had been supported by coal and heated uniformly, expansion or lengthening of the bars would have been uniform and no distortion would have occurred.

(2) If the bars had not been supported by coal and still heated uniformly, thermal growth would have been uniform. Furthermore, analysis indicates that if the temperature exceeded 1100°F, the bars could not support their own weight. But, such a distortion would have been downward, opposite to that actually observed.

---

* Tensile tests were not performed on the solid web bar since removing the material necessary for such tests would have destroyed the structural integrity of the bar. Such destruction was not considered advisable at the time.

DISCUSSION (continued)

(3) If the bars had not been supported by coal and heated non-uniformly the tops of the bars would have been at a higher temperature than the bottoms since the tops would have seen radiant heat from the oven roof while the bottoms would not have seen any radiant heat from the freshly charged coal. Such a situation would have resulted in a downward deflection. Furthermore, this deflection would have recovered upon cooling.

(4) If the bars had been supported by coal and heated non-uniformly it is believed that the failures actually observed would have occurred as described below.

The failure mechanism proposed is the fourth case where the bars suffered differential thermal expansion which resulted in vertical distortion. In the region of failure (last 20 to 25 ft. of both bars) the top of each bar is believed to have been significantly hotter than the bottom. The bottom was at least partially resting on coal in the oven so that downward deflection was restrained. With this restraint, the bars were unable to absorb the differential thermal elongation from top to bottom by a downward deflection. Some of the differential length was absorbed by elastic compression at the top and elastic tension at the bottom. With the top of the bar hotter than the bottom, the top also possessed a lower yield strength. Therefore, when additional strain had to be absorbed the top suffered plastic (permanent) compression while the bottom suffered additional elastic (recoverable) tension. The open web bar was unable to support the compressive load and it therefore buckled; whereas the solid web bar suffered plastic compressive strain. When the bar was removed from the oven and cooled down so that the top in each case was at the same temperature as the bottom the top became shorter than the bottom due to either the buckling or plastic compression suffered at the higher temperature. The bars absorbed this differential length by deflecting upward and thereby putting the shorter top on a shorter arc than the bottom. When the bars cooled upon removal from the ovens, the upward deflection was not significantly restrained.

DISCUSSION (continued)

Sample calculations for this proposed mechanism for the solid web bar, assuming the top reached a temperature between 1000°F and 1250°F, showed that the temperature differential would have had to be between 460°F and 320°F.

Without a detailed thermal analysis or actual temperature measurements, it can not be clearly established that such temperature differentials can in fact occur. However, the failure history and design considerations support this hypothesis.

The solid web bar obtained its upward distortion gradually and at least partially outside any oven. It obtained some distortion after the eight minute exposure and before leveling the next oven. Between this next oven and the oven it could not enter it obtained additional distortion. This comports well with the concept of a bar cooling and distorting upward, as it cools.

A comparison was made between the design of this solid web bar and the design of a bar which had given satisfactory service for more than fifteen years prior to being replaced by this solid web bar (see Figure 62). Thermal consideration of both designs indicated a probable reason why the solid web bar failed while the old design bar had not failed even though it saw similar service including long time exposures in the interior of the ovens. The solid web bar had considerably more top surface area exposed to radiant heat than the old design. In addition the solid web bar also had considerably less mass along its vertical length to carry away heat from the top surface. Furthermore, the situation with the open web bar was even more extreme since it had the same area exposed to roof radiation as the solid web bar but almost no web to carry heat from the top surface. This fact may explain why the open web bar failed more rapidly than the closed web bar.

The thermal differentials proposed could have resulted from the exposure of the top of the bars to greater radiant heat than the bottom. The tops of the bars would see radiant heat from the roof which the bottoms would not. In fact, the bottoms of the bars could have been buried in coal and insulated from any radiant heat. The design considerations discussed above indicate why such a thermal imbalance would not be corrected by internal

DISCUSSION (continued)

conduction through the webs of the bars.

CONCLUSIONS

(1) There were no material defects in either bar. The steel in both bars met the specifications of ASTM A-36 structural steel.

(2) No evidence was present to indicate that the failures were caused by overheating.

(3) Failure was caused by differential heating in the bars resulting from an interaction between the design of the bars and long exposure times in the coke ovens.

To prevent similar failure in the future, several recommendations should be followed.

(1) Set a maximum exposure time in each oven to eliminate excessive heating of the bars. This should become more practical after the use of the inferior larry car is discontinued and the incidence of charging hole plug-up is eliminated.

(2) Redesign the bars to eliminate excessive heat buildup in the top surface or employ the old design bar which calculations now show is usable with the AISI improved procedure[1].

---

[1] K. R. Kortlandt,"AISI Coal Charging System, Coke Oven Leveler Bar," memo to J. H. Stoltz dated December 9, 1971.

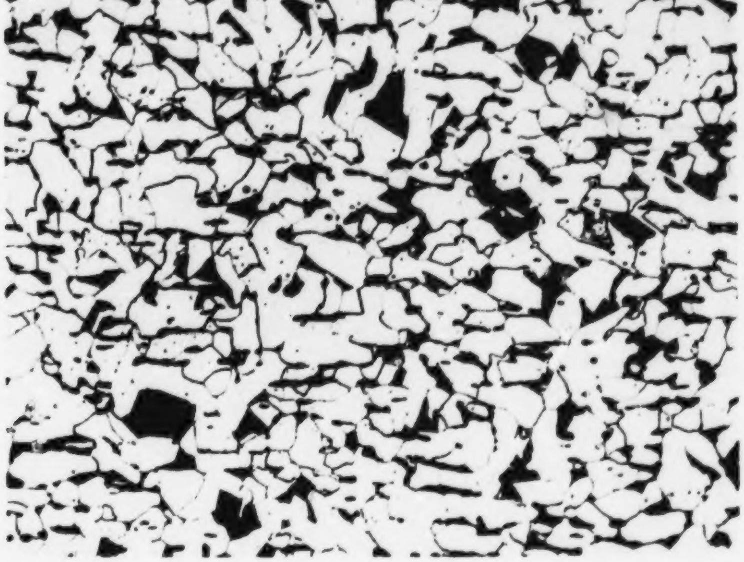
Table 22. CHEMICAL ANALYSIS

	(WEIGHT %)						
	C	Mn	Si	S	P	Al	O
ASTM A-36 specification	.26 max	--	--	.05 max	.04 max	--	--
Solid web leveling bar							
Test from 1' location	.21	.74	.033	.022	.006	.005	--
Test from 41' location	.20	.74	.035	.024	.006	.005	--
Open web leveling bar	.21	.64	.033	.017	.012	.005	.091

Table 23. MECHANICAL TEST RESULTS

	Yield Strength (.2% offset,psi)	Tensile Strength (psi)	Total Elongation (% in 2")	Uniform Elongation (%)
ASTM A-36 specification Open web leveling bar	36,000 min	58,000/ 80,000	23 min.	-
Unbuckled web	44,400	72,840	38.0	26.5
Buckled web	40,400	64,530	35.5	26.5

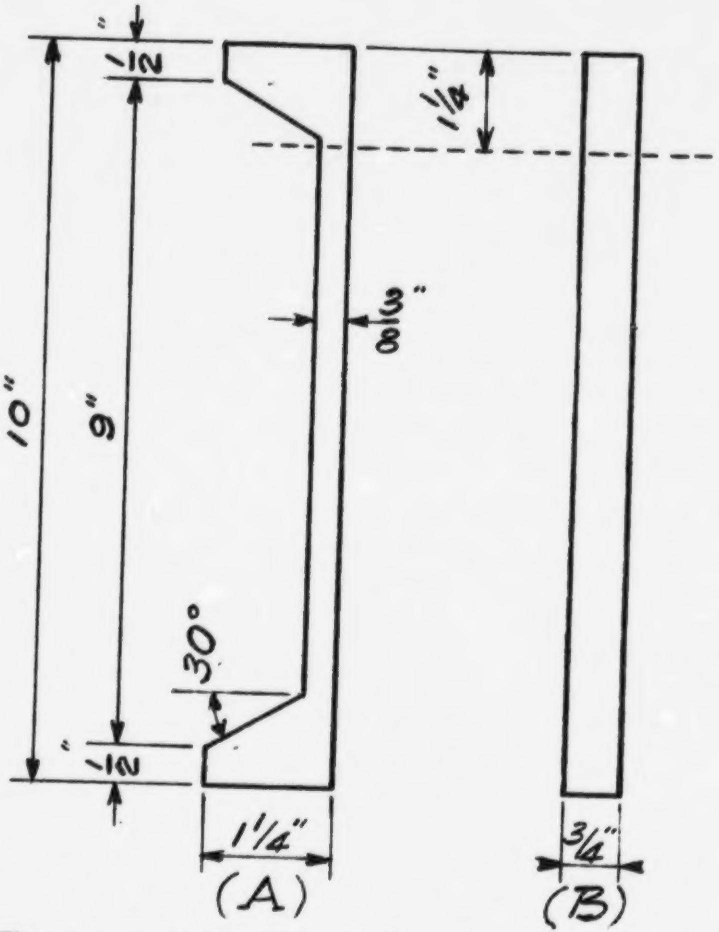
MICROSTRUCTURE - LEVELER BAR STEEL



MICROSTRUCTURE TYPICAL OF THE STEEL IN BOTH NEW BARS - TYPICAL OF AS HOT ROLLED PLAIN CARBON STEEL.

ETCHANT: 2% NITAL 200X

FIGURE 61


1/2"
9"
10"
3/8"
30°
1/2"
1 1/4"
1 1/4"
3/4"
(A)
(B)

LEVELER BAR WEB

CROSS SECTIONS OF THE (A) SOLID WEB BAR WHICH FAILED AND THE (B) OLD DESIGN BAR WHICH GAVE MORE THAN 15 YEARS SATISFACTORY SERVICE BEFORE BEING REPLACED BY THE SOLID WEB BAR.

Figure 62

REPORT BY N. C. DeLUCA, J&L RESEARCH

INTRODUCTION

In conjunction with the AISI/EPA coal charging system at the Pittsburgh Works By-Product Department, Koppers installed a new light-type leveler bar. Koppers believed that the light-type leveler bar was necessary to enhance the ability of the bar to support itself in the coke oven whenever the normal coal charge upon which the bar rests was absent. Subsequently, two of the new light-type leveler bars failed by assuming an upward deflection of 8 inches along the first 20 feet of the length of the bar. Since the failures appeared to be the result of overheating and/or uneven heating of the bars, a study to characterize the thermal cycling of the bars was conducted.[1]

PRELIMINARY STUDY

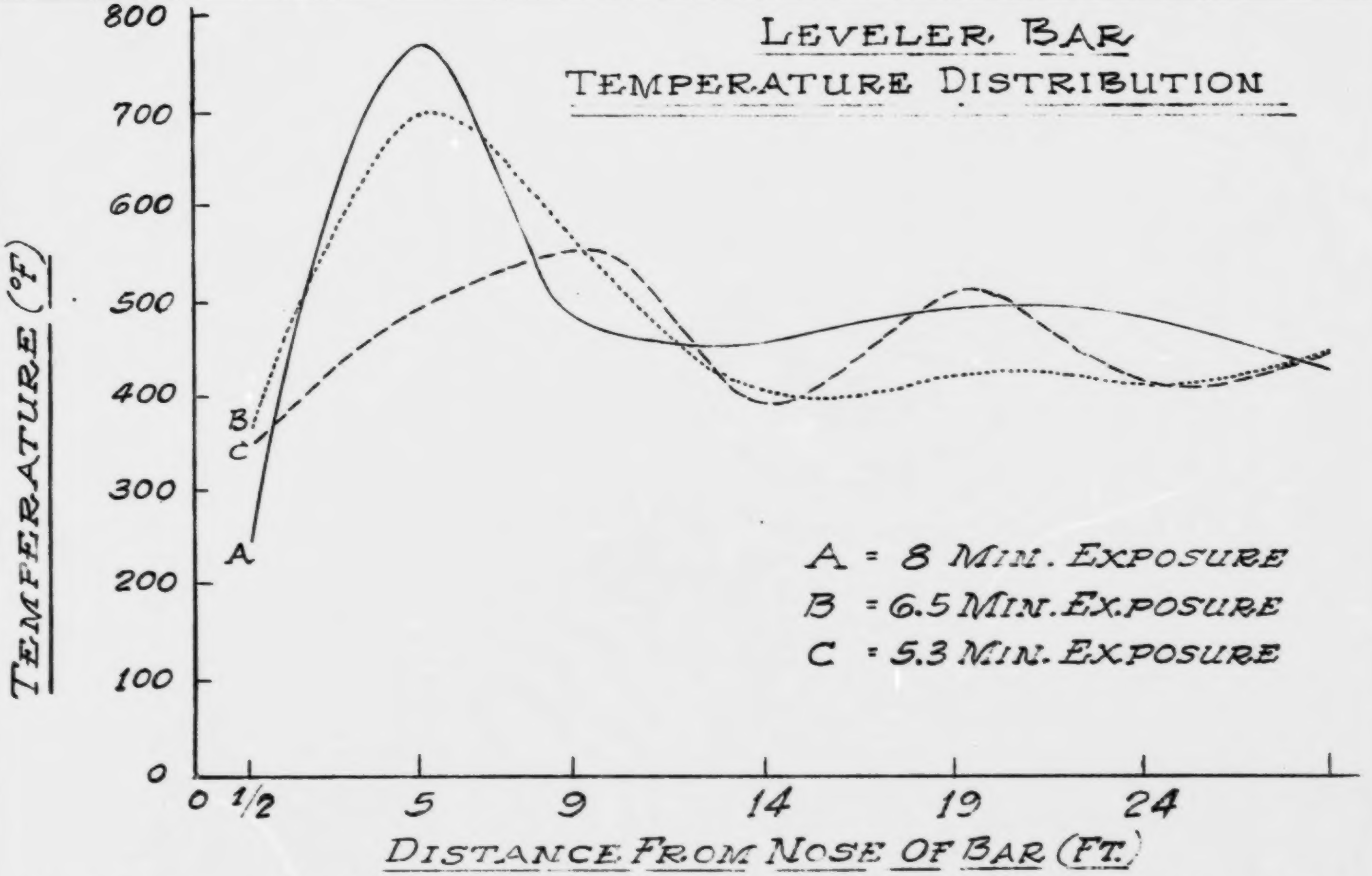
In the preliminary study a contact pyrometer was used to measure surface temperatures along the length of the old heavy-type leveler bar. The old heavy-type leveler bar was chosen for this study because both of the light-type leveler bars supplied by Koppers were warped and out of service. In addition, the continued use of the old heavy-type leveler bar was under consideration as it had performed well in service since the construction of P-4 battery.

The surface temperatures were measured after normal and extended coke oven leveling operations. The purpose of these measurements was to locate the critical areas or hot spots of the bar[2].

Typical temperature distributions along the length of the bar are shown in Figure 63. In addition, a typical temperature

[1] Memo, L.S. Pope to J.H. Stoltz, "Coke Oven Leveler Bar, Service Job No. 61-71", 1/19/72.

[2] Memo, N.C. DeLuca to E.A. Mizikar, "Status of the Coke Oven Leveler Bar Program", 4/20/72.



TEMPERATURE DISTRIBUTION ALONG THE TOP OF THE LEVELER BAR

Figure 63

PRELIMINARY STUDY (continued)

distribution along both the length and width of the bar is shown in Figure 64. The temperature peaks located along the bar are related to the position of the coke oven charging holes over the leveling bar when the bar is fully extended into the oven. As shown in Figure 65 the highest temperature occurred directly under the No. 3 charging hole and the second highest temperature was under No. 2 charging hole.

FINAL STUDY

In the final study with the heavy-type leveler bar, continuous temperature measurements were taken at the location shown in Figure 66. The measuring sites were selected on the basis of the surface temperature measurements obtained in the preliminary study. The function of each measuring site was as follows:

Site 1 - To measure the nose temperature of the bar and to determine the ΔT between the nose and the hottest location of the bar.

Sites 2, 3 and 4 - To measure the temperature at the hottest location of the bar and to determine the ΔT between the top and the bottom of the bar.

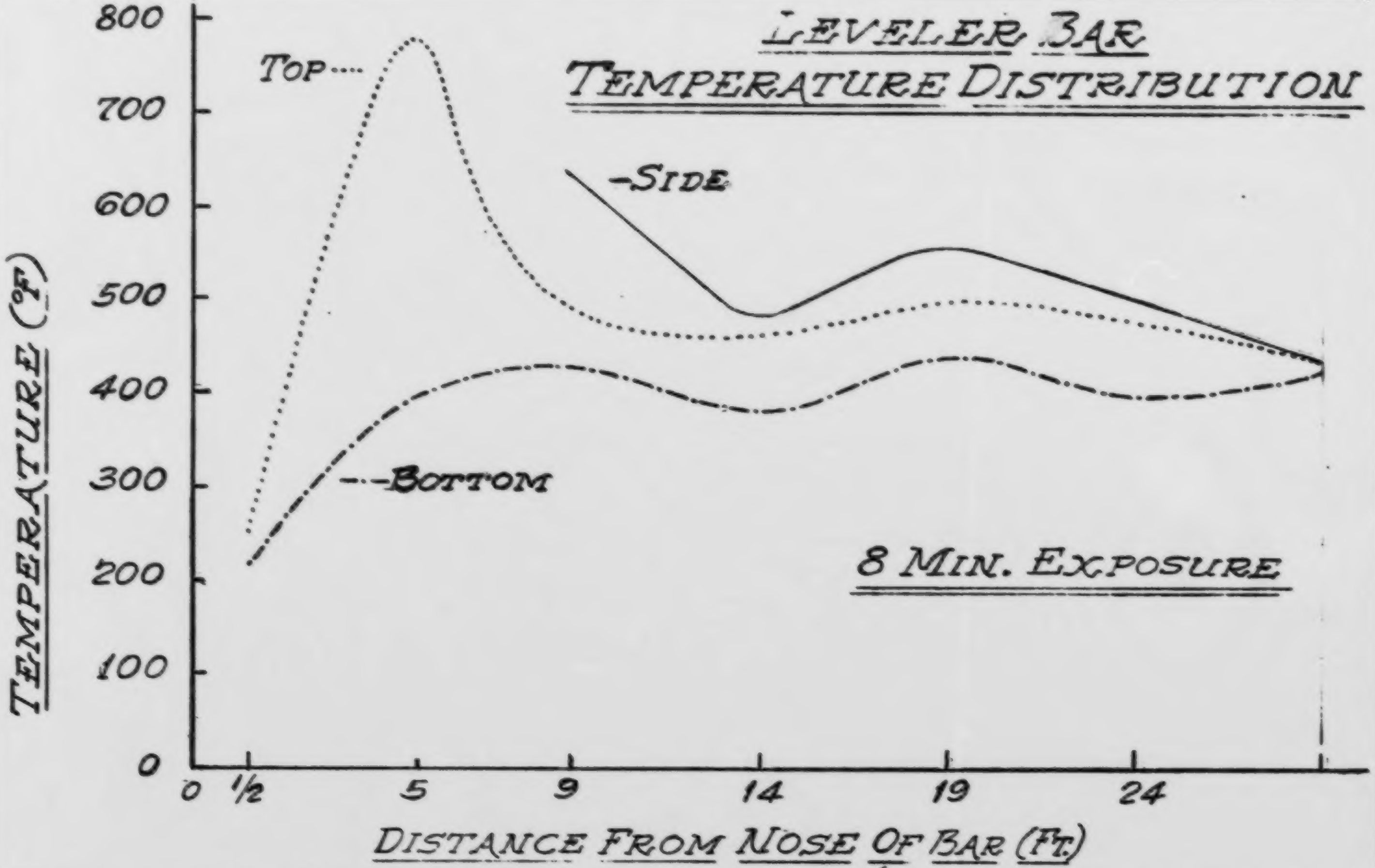
Site 5 - To determine the ΔT between the hottest location and a point on the bar that is the same distance from the hot spot as No. 1 but toward the rear of the bar.

Site 6 - To measure the temperature of the secondary hot spot of the bar.

Site 7 - To measure the temperature of the bar between the No. 1 charging hole and the ascension pipe.

NOTE: The thermocouple at Site No. 4 failed shortly after installation

The leveler bar temperature measurements were obtained by inserting 1/16", sheathed, type K thermocouples into holes drilled in the leveler bar, as illustrated in Figure 66. The holes were first drilled through the leveler bar, then the opening on the



TEMPERATURE DISTRIBUTIONS FOR TOP, BOTTOM AND SIDE OF LEVELER BAR

Figure 64

LEVELER BAR IN COKE OVEN

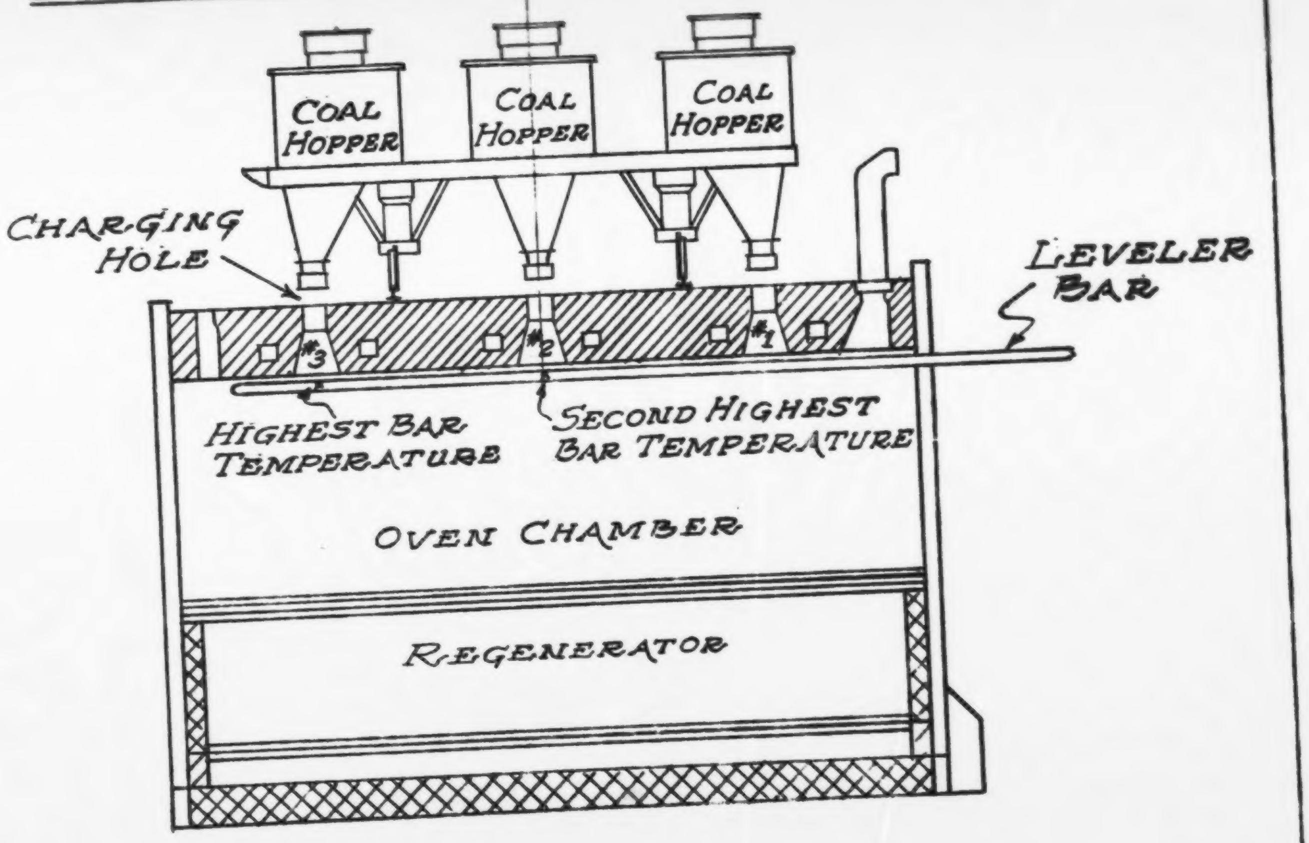

COAL HOPPER
COAL HOPPER
COAL HOPPER
CHARGING HOLE
LEVELER BAR
#3
#2
#1
HIGHEST BAR TEMPERATURE
SECOND HIGHEST BAR TEMPERATURE
OVEN CHAMBER
REGENERATOR

Figure 65

THERMOCOUPLE LOCATIONS IN LEVELER BAR

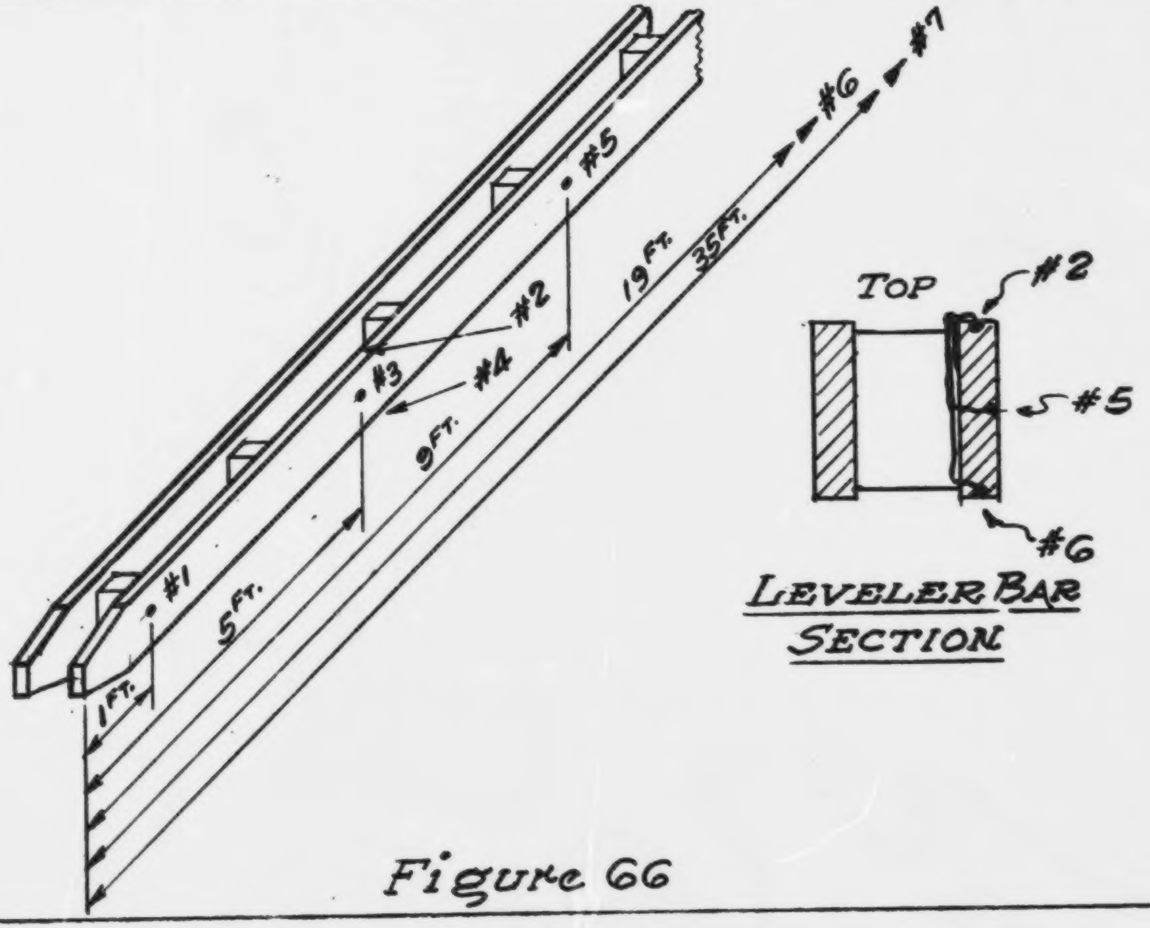

#1
#2
#3
#4
#5
#6
#7
1 FT.
5 FT.
9 FT.
19 FT.
35 FT.
TOP
#2
#5
#6
LEVELER BAR
SECTION

Figure 66

surface to be measured was tack welded shut to insure that the thermocouple measuring junction would be in close contact with the surface after its insertion. The seven thermocouples embedded in the leveler bar were fed back along the top of the bar through a 1/2" protection tube to a thermocouple switching unit. The switching unit, illustrated in Figure 67, multiplexed the seven thermocouple outputs into a single pulsed output. The output, a series of 3-second pluses interrupted by a sequencing pulse, was carried over thermocouple extension wire to a continuous strip chart recorder. A weight driven thermocouple wire retracting reel, also shown in Figure 67, permitted a 40 ft. movement of the leveling bar while the temperatures were being recorded.

During the final study, 106 coke oven leveling operations and the cooling periods between the operations were recorded. The leveling operations that were monitored included normal and extended operations, up to 16 minutes, utilizing both the No. 3 table-fed and the No. 4 gravity-fed larry cars and both the high and the low steam pressure adapted coke ovens.

RESULTS AND CONCLUSIONS

The information gathered in monitoring the leveling operations was partially analyzed by both multiple regression and graphical methods before the analysis of the data was curtailed by a change in project priorities. The multiple regression model and the data will be kept on file at Graham Laboratory for future analysis if required.

The data gathered from 106 leveling operations consists of approximately 5,000 time-temperature data points for the heating cycles and 18,000 time-temperature data points for the cooling cycles. In addition to the time-temperature relationship, the following information was also obtained for each operating cycle: the heating time, the larry car, the steam pressure, the number of strokes, the oven number, and the cooling time until the next operation. The data were first subdivided into heat-up and cool-down segments. Multiple regression analyses and individual cycle graphing were then performed for both the heat-up and the cool-down data.

THERMOCOUPLE SWITCHING CIRCUITS

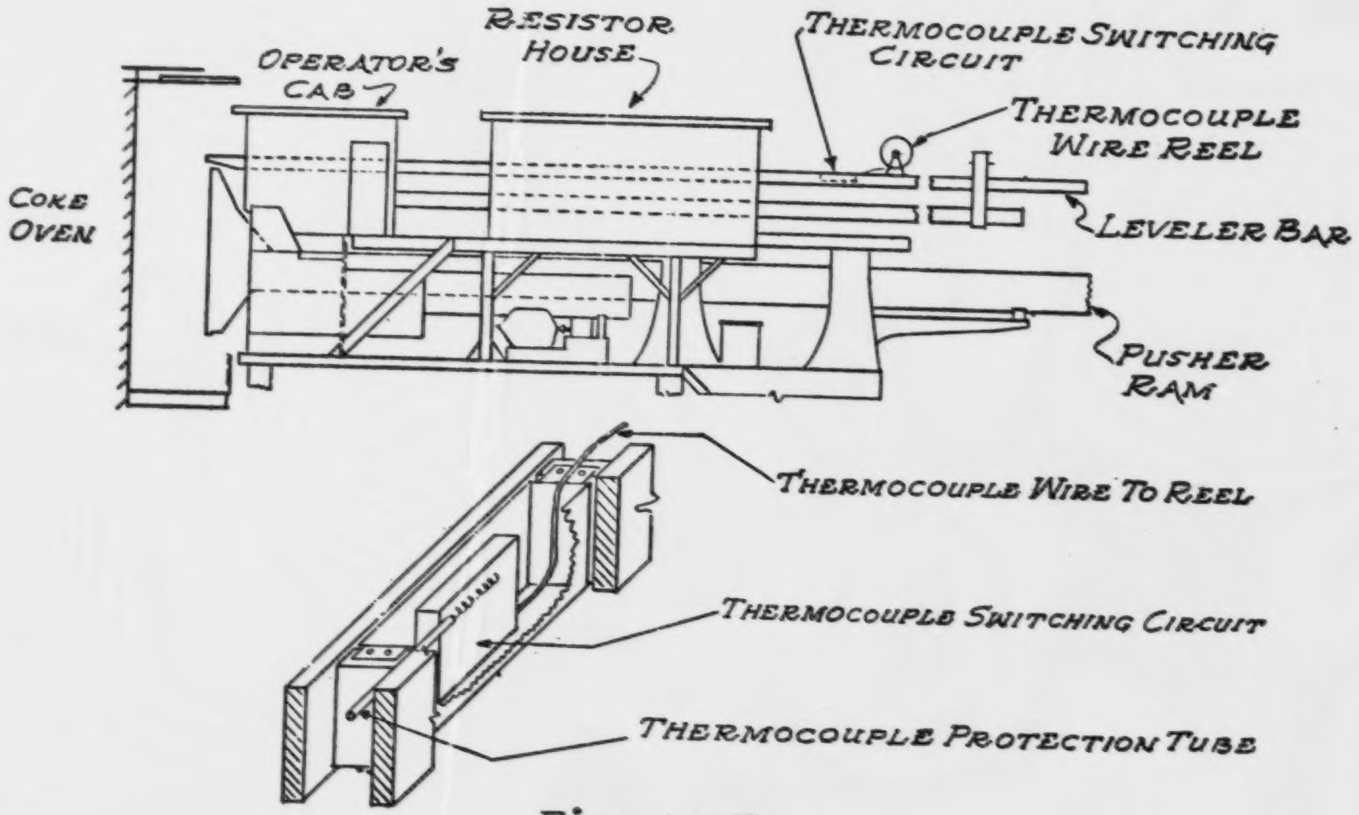

RESISTOR HOUSE
OPERATOR'S CAB
THERMOCOUPLE SWITCHING CIRCUIT
THERMOCOUPLE WIRE REEL
COKE OVEN
LEVELER BAR
PUSHER RAM
THERMOCOUPLE WIRE TO REEL
THERMOCOUPLE SWITCHING CIRCUIT
THERMOCOUPLE PROTECTION TUBE

Figure 67

MULTIPLE REGRESSION ANALYSIS OF THE HEAT-UP DATA

A summary of the leveler bar heat-up data given in Table 24 was generated by multiple regression analysis of the raw data. The table illustrates that the heat-up time of a single leveling operation ranged from 0.88 minutes to 16.9 minutes with an average leveling time of 2.92 minutes. The table also illustrates that the temperature of the leveling bar ranged from 200°F to 1160°F. Within these confines, the initial bar temperatures ranged from an average of 354°F at site 1 to an average of 485°F at site 7 and the final temperatures ranged from an average of 398°F at site 1 to an average of 592°F at site 2. These averages reflect the anticipated temperatures during normal leveling operations.

The results of the multiple regression analysis for the final leveling bar temperatures are listed in Table 25; the details of the analysis are described on page 244. As Table 25 illustrates, the initial temperature at the site is the largest single factor in accounting for the final temperature; it represents from 55 to 76% of the variability. The next largest factor in accounting for the final temperature is $\sqrt{\text{heating time}}$, which together with the initial temperatures represents from 83 to 87% of the variability. The final temperature at site 1 differs from the other sites in that its final temperature is not significantly related to heating time, but is almost completely explained by initial temperature. A likely explanation for this relationship is that the bar is advanced along with the smoke box to a position directly in front of the chuck door to await the start of the coal charging. In this position the nose of the bar is exposed to direct radiation from the coke oven while the rest of the bar is still outside the oven. Thus, the manner in which the nose is heated is significantly different from the rest of the bar. The other variables that affect the final temperature of the bar are the larry car and the number of strokes during charging. They respectively account for 4% and 2% of the variability of the final temperature. Thus, with the exception of site 1 at the nose of the bar, the four variables: initial temperature, $\sqrt{\text{heating time}}$, larry car, and number of strokes, together account for 88 to 91% of the variability in the final temperatures. No other variable significantly enters into the explanation of final temperature under normal operating conditions. Notably absent was the steam pressure, as it was feared that the high steam pressure necessary with the new charging system would unduly heat the leveling bar under normal operating conditions.

Table 24. PARTIAL SUMMARY OF LEVELER BAR HEAT-UP DATA

Variable	Average	Sigma	Minimum	Maximum
Heating time (min.)	2.92	2.16	0.88	16.9
Strokes	7.23	4.97	3.0	30.0
Steam pressure 1=low, 2=high	1.56	0.49	--	--
Larry car no.	3.15	0.35	--	--
Initial temp.°F 1	354	80	200	580
Initial temp.°F 2	469	152	215	950
Initial temp.°F 3	452	145	210	960
Initial temp.°F 5	478	141	210	990
Initial temp.°F 6	404	111	210	745
Initial temp.°F 7	485	147	240	945
Final temp.°F 1	398	88	260	635
Final temp.°F 2	592	166	287	1160
Final temp.°F 3	546	158	263	1070
Final temp.°F 5	570	147	273	1030
Final temp.°F 6	474	117	283	870
Final temp.°F 7	555	164	270	1080

Table 25. RESULTS OF THE REGRESSION ANALYSIS FOR THE FINAL LEVELING BAR TEMPERATURES

	Site #1	Site #2	Site #3	Site #5	Site #6	Site #7
Standard deviation of the raw data	88°F	166°F	158°F	147°F	117°F	164°F
1st variable in model	initial temp.	initial temp.	initial temp.	initial temp.	initial temp.	initial temp.
% of variability accounted for	76%	55%	59%	64%	60%	64%
2nd variable in model	number of stroks	$\sqrt{\text{time}}$	$\sqrt{\text{time}}$	$\sqrt{\text{time}}$	$\sqrt{\text{time}}$	$\sqrt{\text{time}}$
Comulative % of variability accounted for	88%	83%	82%	87%	86%	78%
3rd variable in model	larry car	larry car	larry car	larry car	larry car	larry car
Comulative % of variability accounted for	89%	87%	88%	91%	88%	85%
4th variable in model	--	number of stroks	number of stroks	--	number of stroks	number of stroks
Cumulative % of variability accounted for	89%	88%	89%	91%	88%	87%
Final standard deviation	28°F	59°F	53°F	43°F	40°F	60°F

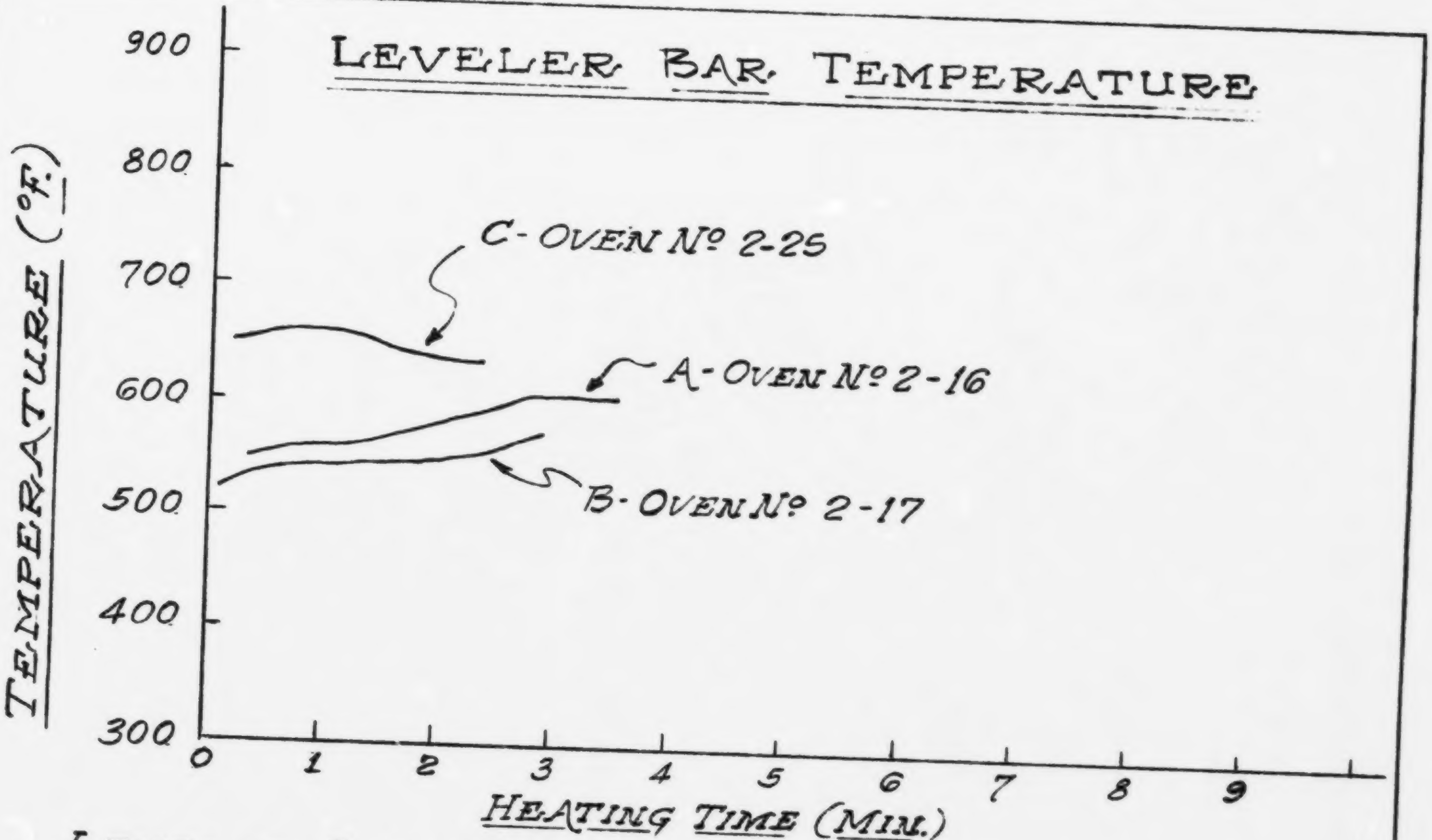
MULTIPLE REGRESSION ANALYSIS OF THE HEAT-UP DATA (continued)

Additional multiple regression analyses were run using the delta temperatures and the rates of temperature rise as the dependent variable. Other than the initial temperatures being a significant factor, the results were mixed with the exception that the strokes per minute was the second most significant factor affecting the rate of temperature rise. An inverse relationship exists which dictates that the more often the bar is stroked per minute the slower the rate at which the bar will heat. This relationship is best explained by considering the ratio of time the bar spends in the oven to the time the bar spends out of the oven during a single stroking cycle. If the ratio were 1:1 the rate at which the bar was stroked should have little significance; but this is not the case in actual practice. Usually the operator extends the leveler bar, pauses, then retracts the bar. The bar is retracted from 20 feet to full stroke and then immediately re-inserted into the coke oven. The pause in the oven is the longest when the bar is stroked the least number of times per minute. Thus, by stroking the bar more frequently or by not pausing in the oven the rate of temperature rise of the bar can be reduced.

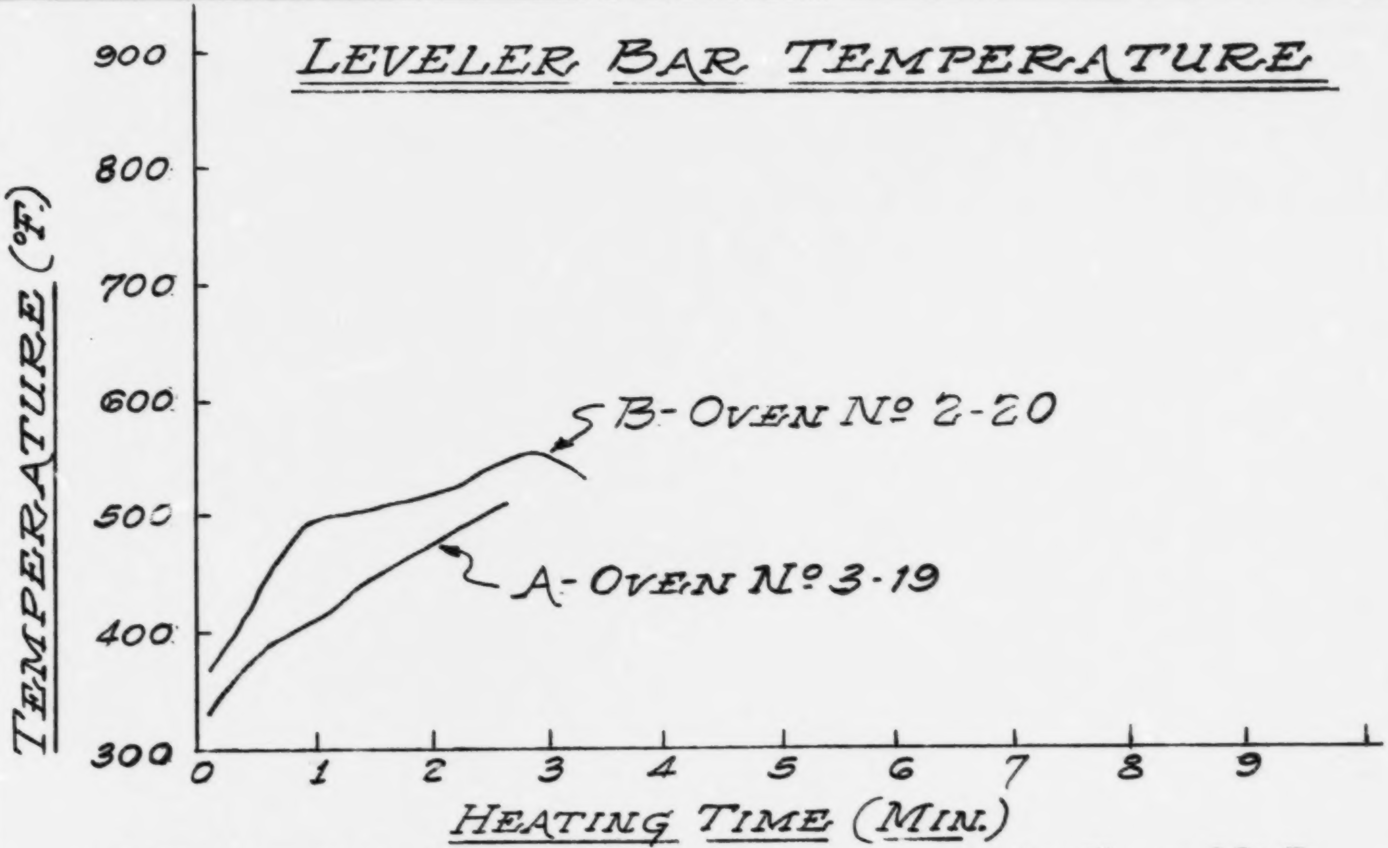
GRAPHICAL ANALYSIS OF THE HEAT-UP DATA

The leveling bar temperature at site 2 was plotted as a function of the heating time for some of the leveling operations. These graphs are illustrated in Figures 68, 69, 70 and 71 for the No. 3 and No.4 larry cars charging under high and low pressure steam.

The graphs in general illustrate some of the inconsistencies in the leveler bar heating during a coke oven charging. These inconsistencies are readily apparent in Figure 70, in which under similar operating conditions the temperature of the bar increased in different fashions, and in one case (C) actually decreased during the leveling operation. The manner in which the leveler bar heats is related to the manner in which the coal enters the coke oven. The coal being cooler than the leveling bar tends to cool the bar when it is dropped quickly and when air is restricted from entering the coke oven through the charging holes. A comparison of Figure 68 with Figure 69 and Figure 70 with Figure 71 demonstrates that the No. 3 larry car is more efficient

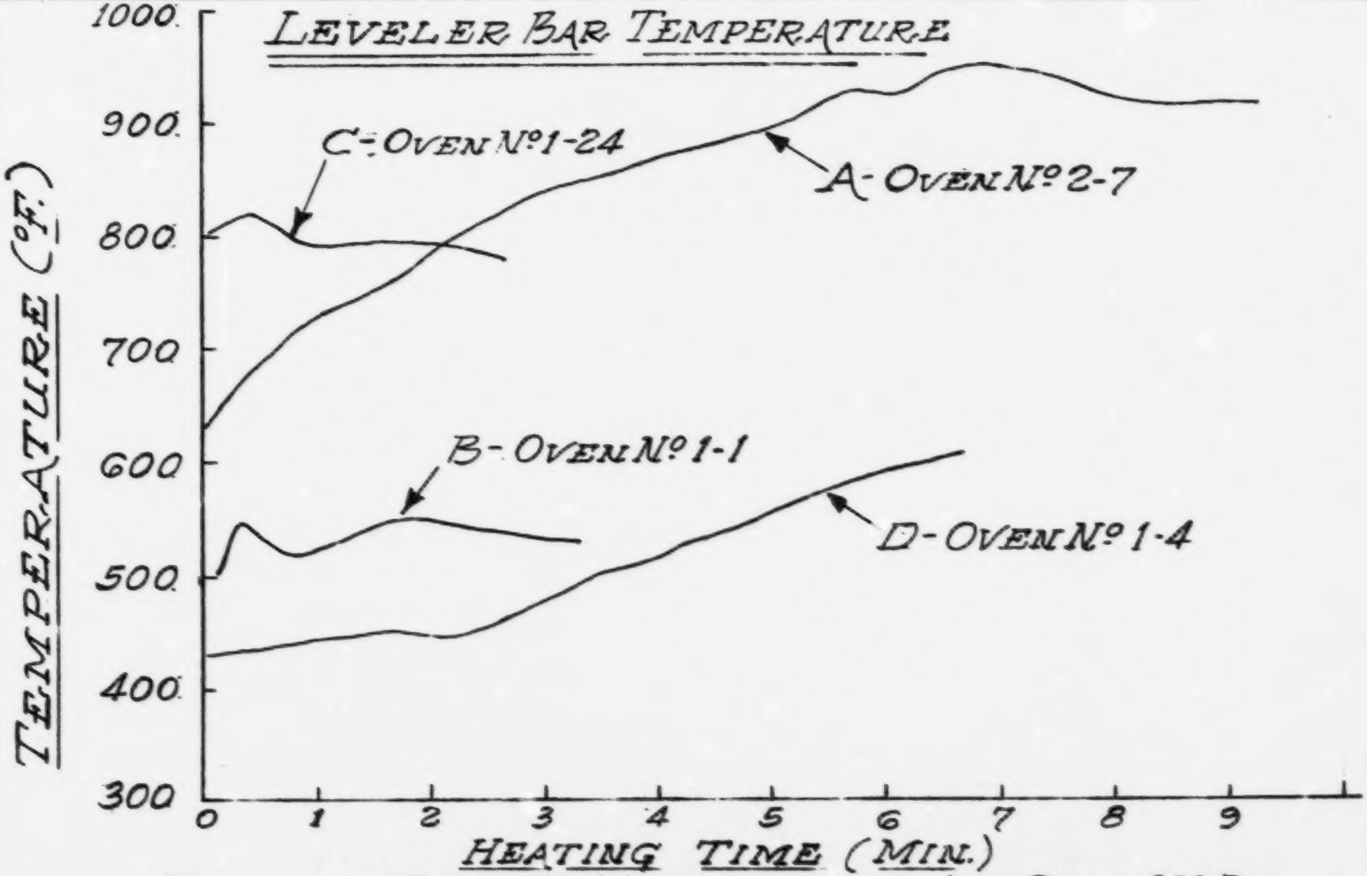


LEVELER BAR TEMPERATURE AT SITE №2
HIGH PRESSURE STEAM AND №3 LARRY CAR
Figure 68



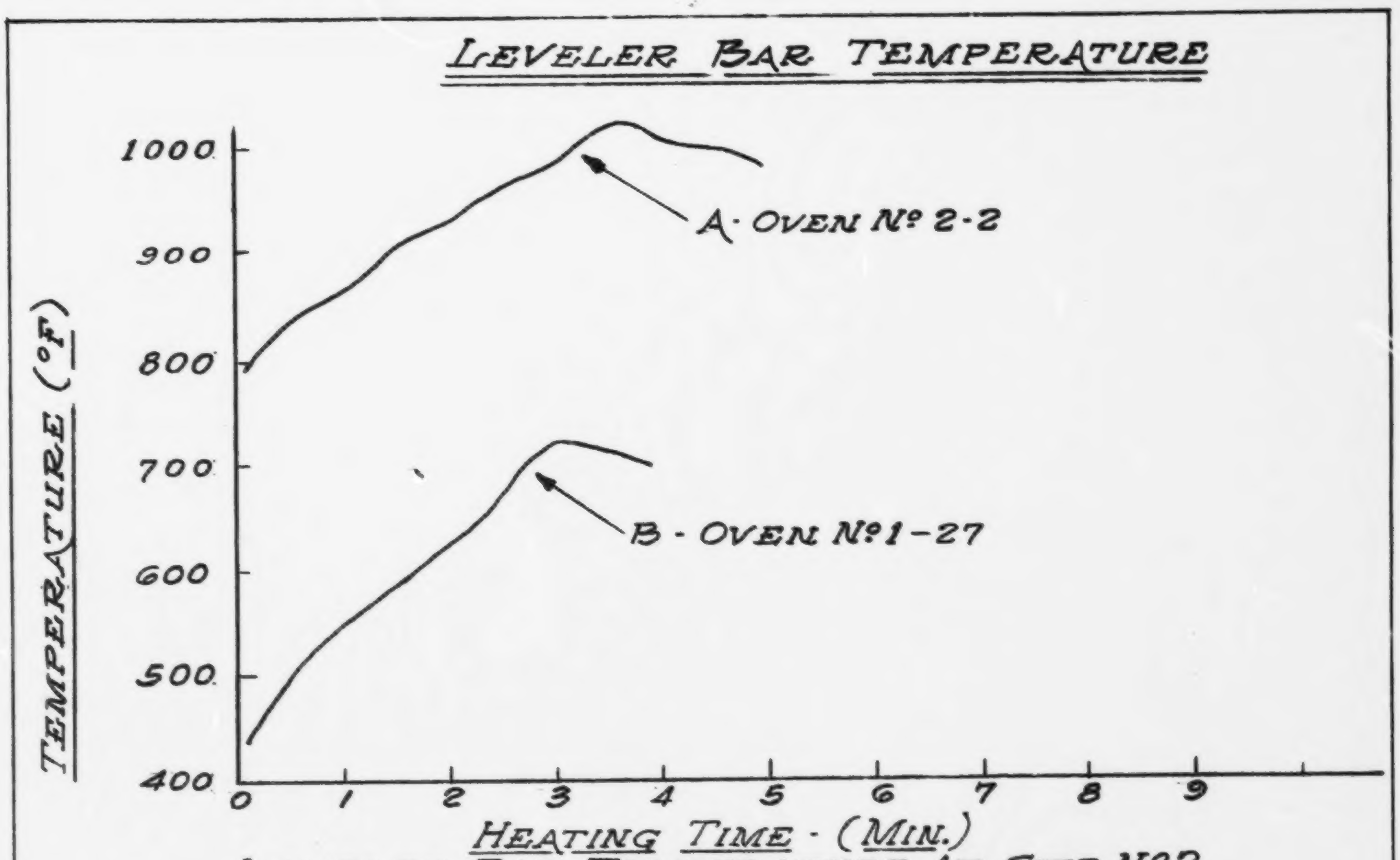
LEVELER BAR TEMPERATURE AT SITE № 2
HIGH PRESSURE STEAM AND № 4 LARRY CAR

Figure G9



LEVELER BAR TEMPERATURE AT SITE No 2
LOW PRESSURE STEAM AND No 3 LARRY CAR

Figure 70



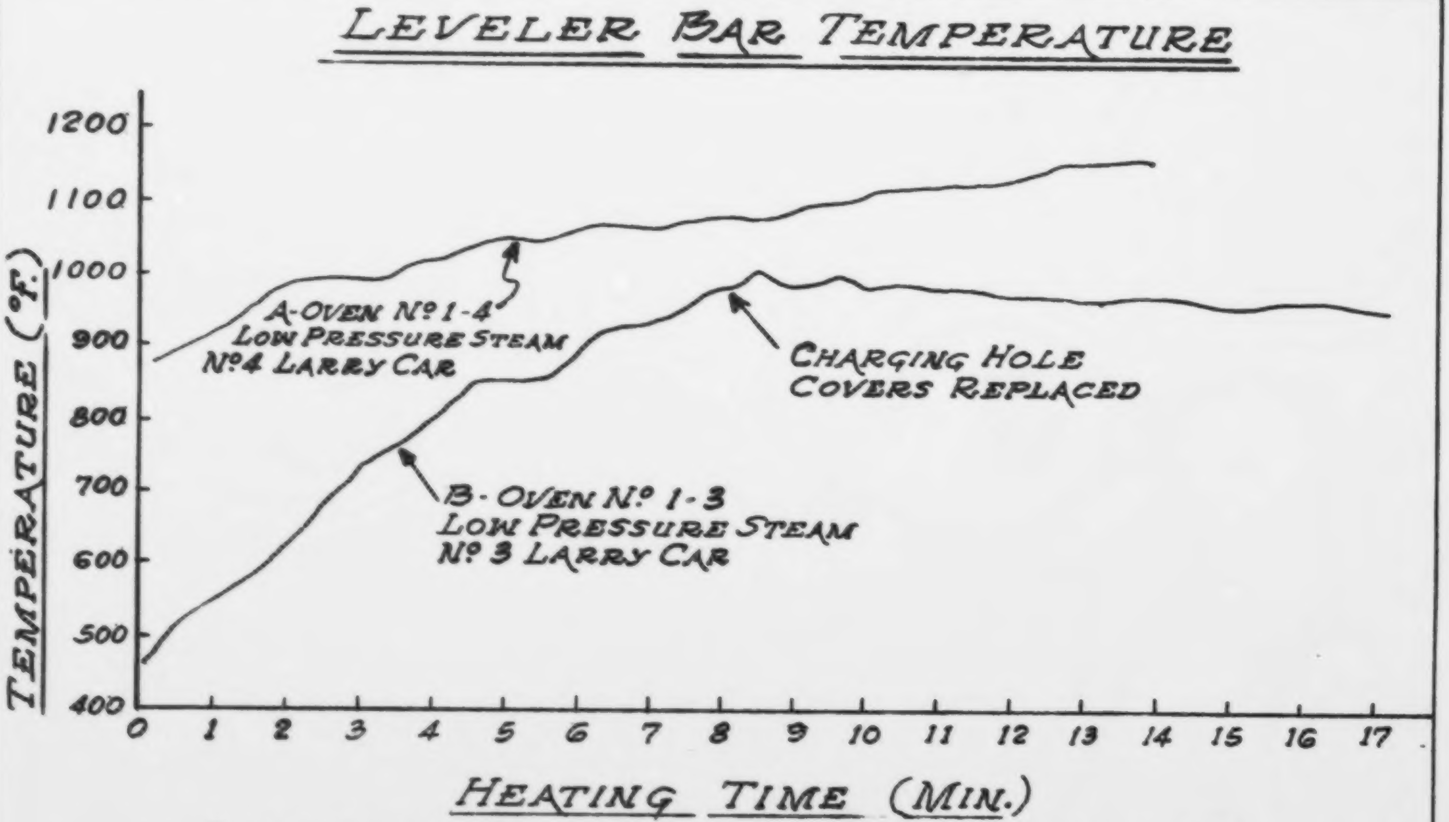
LEVELER BAR TEMPERATURE AT SITE No 2
LOW PRESSURE STEAM AND No 4 LARRY CAR
Figure 71

in charging the coal and in limiting the temperature rise of the leveler bar. This observation agrees with the multiple regression analysis, which found that next to the initial temperature of the bar and the heating time, the larry car was the most important factor in the leveling operation. Along with this condition the No. 4 larry car usually takes longer to charge an oven and thereby reinforces the conviction that the No. 4 larry car should be used no more than absolutely necessary.

The graphs also support the conclusion that the steam pressure is of little consequence in the heating rate of the leveler bar. A comparison of Figure 68 with Figure 70 and Figure 69 with Figure 71 shows no significant difference between high and low steam operating conditions.

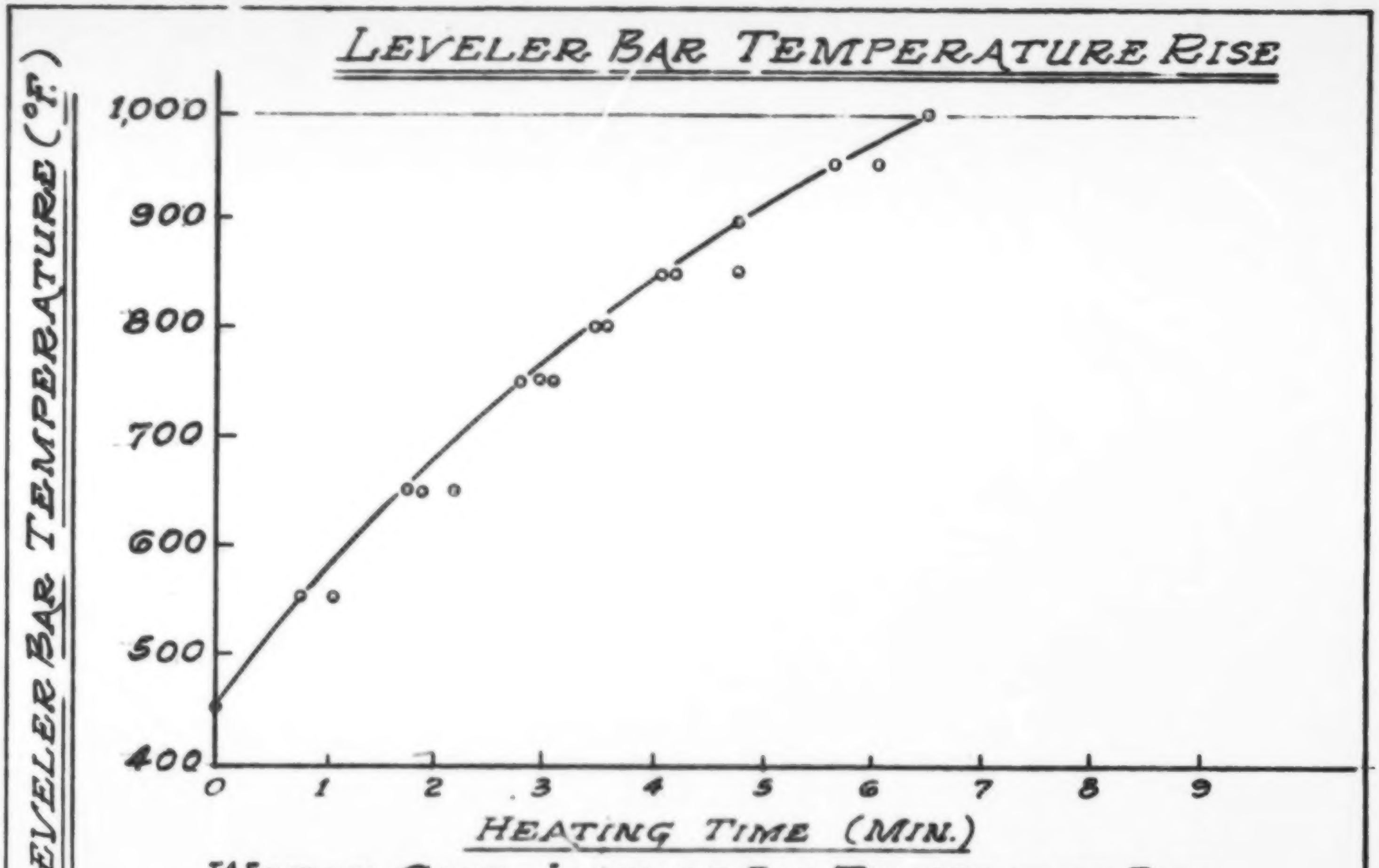
Two abnormally long leveling operations are illustrated in Figure 72. Curve A represents a leveling operation using No. 4 larry car from which the coal would not feed properly; air was entering the charging holes during the entire operation. The temperature of the bar climbed steadily during the entire leveling operation. In contract Curve B represents a leveling operation using the No. 3 larry car in which the leveler bar was deliberately permitted to remain in the oven after the coal charging was complete. In this case the covers were replaced on the charging holes after the larry car was emptied in order to prevent the entrance of air into the oven. The temperature of the bar climbed steadily until the covers were replaced and then began to drop slightly, possibly as a result of being in contact with the cooler coal. This comparison illustrates the importance of replacing the charging hole covers as quickly as possible in the event that the leveler bar must remain in the oven due to an equipment failure.

The rate of temperature rise of the leveling bar fluctuates during a normal leveling operation in response to the oven conditions; the worst case heating of the bar is usually evident only for short periods of time during the leveling operation. Figure 73 contains a composite graph of the leveler bar temperature which was constructed by combining the worst case heating segments from the graphs of numerous leveling operations. The graph illustrates that a leveler bar with an initial temperature of



LEVELER BAR TEMPERATURE AT SITE No 2
EXTENDED LEVELING OPERATIONS

Figure 72



WORST CASE LEVELER BAR TEMPERATURE RISE

Figure 73

GRAPHICAL ANALYSIS OF THE HEAT-UP DATA (continued)

450°F could reach a 1000°F temperature limit in 6.5 minutes if the worst case observed heating conditions exist for the duration of the leveling operation. While this situation is highly unlikely, it is possible for the temperature to exceed 1000°F if the leveler bar has a high initial temperature and is heated for a short period under worst case conditions.

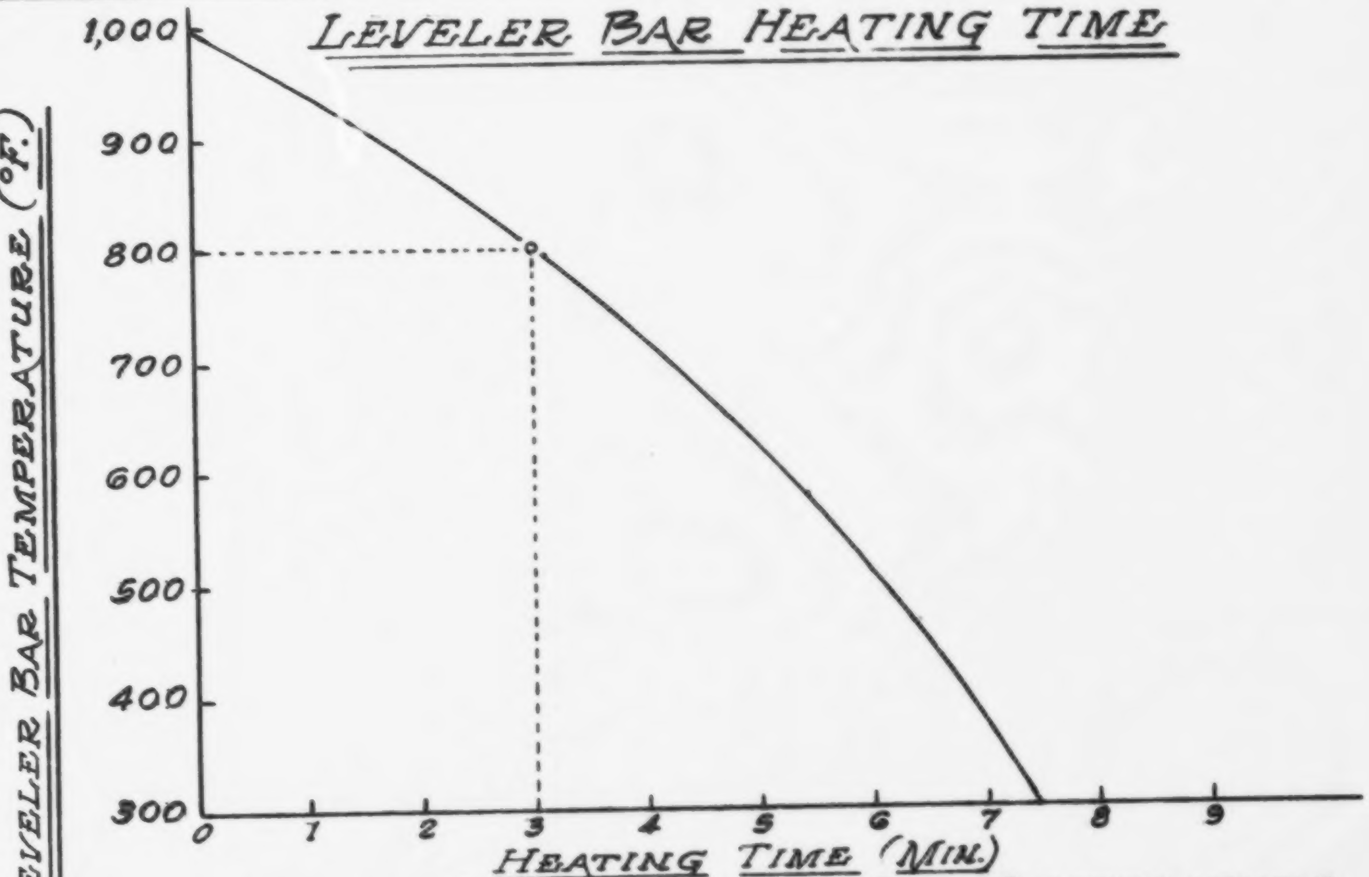
The graph in Figure 74 gives the maximum initial temperature of the leveler bar as a function of the safe heating time under the worst case heating conditions. To reduce the possibility of the leveler bar reaching 1000°F, the normal operating time should be within the safe heating time. During the 106 operations that were monitored, the average leveling time was 2.92 or approximately 3 minutes. As can be seen in Figure 74, a normal 3 minute leveling operation would be safe under the worst case heating conditions as long as the leveling bar was initially below 800°F.

This criterion would have prohibited the leveling operation (A) illustrated in Figure 72 which began with an initial temperature of 875°F and reached a final unsafe leveler bar temperature of 1160°F.

RECOMMENDATIONS

To substantially reduce the risk of overheating the leveler bar, 800°F should be adopted as the maximum initial temperature with which a leveling operation can be performed. The 800°F criterion can be utilized by having the operator check the leveler bar temperature with an 800°F Tempilstik whenever he suspects the bar is in danger of overheating. He should definitely check the bar after every extended leveling operation. To check the bar temperature, the operator should rub the Tempilstik on the top of the bar 5 feet back from the nose; the location is directly opposite the operator's door.

Implementation of this procedure along with limiting the operating time of the leveler bar to 3 minutes in cases where the bar has recently been heated to above 800°F will substantially reduce the risk of overheating the leveler bar. To completely eliminate all risk of overheating would require a somewhat impractical procedure of establishing a time limit on the operation based upon a difficult measurement of the bar's initial temperature.



MAXIMUM INITIAL LEVELER BAR TEMPERATURE
AS A FUNCTION OF SAFE HEATING TIME
Figure 74

MULTIPLE REGRESSION ANALYSIS OF HEAT-UP DATA

To conduct a multiple regression analysis the following information was punched on IBM cards using one card for each operating cycle:

1 The coke oven number
2 Dummy number (part of the coke oven number)
3 The heating time of the cycle
4 The number of leveling strokes during the cycle
5 The steam pressure (either high or low)
6 The larry car used (either #3 or #4)
7 The initial temperature at site #1
8 The initial temperature at site #2
9 The initial temperature at site #3
10 The initial temperature at site #5
11 The initial temperature at site #6
12 The initial temperature at site #7
13 The final temperature at site #1
14 The final temperature at site #2
15 The final temperature at site #3
16 The final temperature at site #5
17 The final temperature at site #6
18 The final temperature at site #7
19 The cooling time till the next cycle

Using the punched data the following additional variables were generated during the regression analysis to provide a larger basis for correlation:

20 The temperature change (DELTA TEMP) at site #1
21 The temperature change (DELTA TEMP) at site #2
22 The temperature change (DELTA TEMP) at site #3
23 The temperature change (DELTA TEMP) at site #5
24 The temperature change (DELTA TEMP) at site #6
25 The temperature change (DELTA TEMP) at site #7
26 The average rate of temperature rise at site #1
27 The average rate of temperature rise at site #2
28 The average rate of temperature rise at site #3
28 The average rate of temperature rise at site #5
30 The average rate of temperature rise at site #6
31 The average rate of temperature rise at site #7

32 The average strokes per minute during the cycle
33 The inverse time ($1/T$)
34 The square root of the time ($\sqrt{T}$)
35 The square of the time(T^2)
36 The inverse square root of the time ($1/\sqrt{T}$)
37 The inverse square of the time ($1/T^2$)

The multiple regression analysis provides three outputs: a summary listing of the variables containing the average, sigma, minimum and maximum values; a full correlation matrix listing of the correlation coefficients for the relationships between all the variables; and regression equations giving a chosen variable as a function of the other variables.

The summary listing of all the measured variables is illustrated in Table 26. The table lists the variables by name and number and gives the average, the sigma, the minimum and the maximum values. The minimum and maximum values are given in exponential form.

The full correlation matrix listing of the correlation coefficients for the relationships between all the variables is illustrated in Table 27. The variables are listed by name and number along the side of the matrix and by number along the top of the matrix. The value listed at the intersection of the horizontal and the vertical lines representing two variables is the correlation coefficient. This coefficient can range from .000 which represents a random relationship between the variables to 1.000 which represents a direct relationship between the variables. A correlation coefficient of .25 or greater is generally considered significant and the variable should be included in the potential model.

The potential model is a regression equation which explains a chosen variable in terms of the other variables. In the leveler bar study the final temperature was chosen to be the dependent variable which was to be explained by the independent variables: heating time, strokes, strokes per minute, steam pressure,larry car, initial temperature of the bar, and the mutations of heating time. In choosing the independent variables, interrelated

MULTIPLE REGREASION ANALYSIS OF HEAT-UP DATA (continued)

variables must be avoided; for example, the final temperature should not be determined as a function of the delta temperature and the initial temperature since the delta temperature was calculated from the final temperature and the initial temperature

The potential model for the final leveler bar temperatures at the hottest location, measuring site 2 was:

Final temperature =(.725) initial temp. + (214) heating time + (92.7) larry car number - (4.90) number of strokes $-357^{\circ}F$

TABLE 26

	VARIABLE	AVERAGE	SIGMA	MINIMUM	MAXIMUM
1	OVEN NO.	1.95283	0.82094	1.00000E 00	3.00000E 00
2	DUMMY NO.	13.91510	8.09241	1.00000E 00	2.70000E 01
3	HEATING TIME	2.92498	2.16560	8.80000E-01	1.69600E 01
4	STROKES	7.23585	4.97527	3.00000E 00	3.00000E 01
5	STEAM PRESSURE	1.56604	0.49797	1.00000E 00	2.00000E 00
6	LARRY CAR	3.15095	0.35969	3.00000E 00	4.00000E 00
7	INITIAL TEMP 1	354.33984	80.79964	2.00000E 02	5.80000E 02
8	INITIAL TEMP 2	469.95313	132.22006	2.15000E 02	9.50000E 02
9	INITIAL TEMP 3	452.05688	145.34319	2.10000E 02	9.60000E 02
10	INITIAL TEMP 5	478.66064	141.80518	2.10000E 02	9.90000E 02
11	INITIAL TEMP 6	404.95313	111.46675	2.10000E 02	7.45000E 02
12	INITIAL TEMP 7	485.99072	147.89450	2.40000E 02	9.45000E 02
13	FINAL TEMP 1	398.89606	88.16003	2.60000E 02	6.35000E 02
14	FINAL TEMP 2	592.37769	166.04910	2.87000E 02	1.16000E 03
15	FINAL TEMP 3	546.15137	158.20053	2.63000E 02	1.07000E 03
16	FINAL TEMP 5	570.21729	147.06718	2.73000E 02	1.03000E 03
17	FINAL TEMP 6	474.28320	117.17300	2.82000E 02	8.70000E 02
18	FINAL TEMP 7	555.31177	164.40817	2.70000E 02	1.08000E 03
19	COOL TIME	9.85077	8.43555	0.0	5.50200E 01
20	DELTA TEMP 1	44.54720	42.79738	-5.00000E 01	2.30000E 02
21	DELTA TEMP 2	127.42467	114.91956	-8.00000E 01	4.90000E 02
22	DELTA TEMP 3	94.09441	102.88657	-6.00000E 01	4.25000E 02
23	DELTA TEMP 5	91.55667	90.68958	-3.50000E 01	4.50000E 02
24	DELTA TEMP 6	69.33023	75.88730	-8.00000E 01	3.35000E 02
25	DELTA TEMP 7	69.32080	99.71542	-8.50000E 01	4.35000E 02
26	RATE TEMP. RISE 1	15.42891	12.41218	-2.17391E 01	6.41026E 01
27	RATE TEMP. RISE 2	40.22470	28.68787	-3.96040E 01	1.29825E 02
28	RATE TEMP. RISE 3	29.88936	26.23654	-2.97030E 01	9.69828E 01
29	RATE TEMP. RISE 5	29.68431	22.06635	-1.44628E 01	9.05172E 01
30	RATE TEMP. RISE 6	22.07597	20.36203	-4.49438E 01	7.32759E 01
31	RATE TEMP. RISE 7	21.02705	28.85469	-3.69565E 01	1.03448E 02
32	STROKES/MIN	2.59452	0.94371	1.09091E 00	5.68182E 00
33	INVERSE TIME	0.43848	0.18732	5.89623E-02	1.13636E 00
34	ROOT TIME	1.64299	0.47720	9.38083E-01	4.11825E 00
35	SQR TIME	13.20122	33.44226	7.74400E-01	2.87641E 02
36	INVERSE ROOT TIME	0.64648	0.14401	2.42822E-01	1.06600E 00
37	INVERSE SQR TIME	0.22702	0.19930	3.47655E-03	1.29132E 00

Leveler Bar Study
Summary of Leveler Bar Heat-up Data - 106 Observations

TABLE 27

		1	2	3	4	5	6	7
1	OVEN NO.	1.000						
2	DUMMY NO	-0.051	1.000					
3	HEATING TIME	-0.148	-0.236	1.000				
4	STROKES	-0.112	-0.147	0.846	1.000			
5	STEAM PRESSURE	-0.773	-0.267	0.152	0.084	1.000		
6	LARRY CAR	0.250	0.263	0.179	0.150	-0.269	1.000	
7	INITIAL TEMP 1	-0.011	-0.323	0.137	0.255	0.050	-0.082	1.000
8	INITIAL TEMP 2	-0.008	-0.073	0.121	-0.018	-0.019	0.021	0.562
9	INITIAL TEMP 3	-0.029	-0.038	0.121	-0.029	-0.012	0.036	0.534
10	INITIAL TEMP 5	-0.034	-0.077	0.104	0.042	-0.007	-0.019	0.696
11	INITIAL TEMP 6	-0.020	-0.215	0.099	0.068	0.030	-0.072	0.831
12	INITIAL TEMP 7	-0.040	0.013	0.143	-0.059	-0.014	0.095	0.369
13	FINAL TEMP 1	0.015	-0.322	0.420	0.555	0.039	0.098	0.875
14	FINAL TEMP 2	-0.052	-0.025	0.584	0.392	0.045	0.323	0.329
15	FINAL TEMP 3	-0.037	-0.000	0.538	0.335	0.033	0.368	0.300
16	FINAL TEMP 5	-0.049	-0.039	0.535	0.442	0.027	0.285	0.522
17	FINAL TEMP 6	-0.060	-0.235	0.562	0.520	0.104	0.174	0.698
18	FINAL TEMP 7	-0.008	0.071	0.461	0.206	-0.008	0.420	0.133
19	COOL TIME	0.101	0.018	-0.092	-0.039	-0.092	0.052	-0.028
20	DELTA TEMP 1	0.050	-0.053	0.606	0.663	-0.014	0.357	-0.085
21	DELTA TEMP 2	-0.064	0.061	0.683	0.591	0.090	0.439	-0.270
22	DELTA TEMP 3	-0.015	0.053	0.655	0.556	0.068	0.516	-0.294
23	DELTA TEMP 5	-0.027	0.058	0.706	0.651	0.056	0.492	-0.242
24	DELTA TEMP 6	-0.063	-0.047	0.723	0.704	0.117	0.375	-0.143
25	DELTA TEMP 7	0.047	0.097	0.548	0.428	0.008	0.551	-0.328
26	RATE TEMP. RISE 1	0.229	0.130	-0.022	0.142	-0.188	0.323	-0.271
27	RATE TEMP. RISE 2	0.045	0.299	0.077	0.071	-0.010	0.421	-0.536
28	RATE TEMP. RISE 3	0.112	0.254	0.118	0.102	-0.031	0.523	-0.538
29	RATE TEMP. RISE 5	0.137	0.307	0.100	0.152	-0.087	0.533	-0.494
30	RATE TEMP. RISE 6	0.083	0.145	0.109	0.191	-0.007	0.333	-0.362
31	RATE TEMP. RISE 7	0.154	0.243	0.126	0.074	-0.084	0.521	-0.497
32	STROKES/MIN	0.054	0.152	-0.174	0.294	-0.123	-0.036	0.152
33	INVERSE TIME	0.025	0.155	-0.703	-0.626	-0.065	-0.233	-0.138
34	ROOT TIME	-0.120	-0.227	0.974	0.845	0.134	0.212	0.147
35	SQR TIME	-0.166	-0.219	0.937	0.750	0.152	0.112	0.104
36	INVERSE ROOT TIME	0.050	0.180	-0.803	-0.715	-0.083	-0.238	-0.146
37	INVERSE SQR TIME	0.003	0.118	-0.528	-0.460	-0.055	-0.201	-0.116

		8	9	10	11	12	13	14
8	INITIAL TEMP 2	1.000						
9	INITIAL TEMP 3	0.994	1.000					
10	INITIAL TEMP 5	0.964	0.956	1.000				
11	INITIAL TEMP 6	0.866	0.852	0.937	1.000			
12	INITIAL TEMP 7	0.931	0.949	0.848	0.696	1.000		
13	FINAL TEMP 1	0.422	0.401	0.557	0.682	0.270	1.000	
14	FINAL TEMP 2	0.743	0.751	0.680	0.576	0.770	0.449	1.000
15	FINAL TEMP 3	0.758	0.773	0.688	0.569	0.802	0.418	0.987
16	FINAL TEMP 5	0.796	0.799	0.803	0.724	0.753	0.625	0.938
17	FINAL TEMP 6	0.705	0.696	0.755	0.781	0.592	0.810	0.817
18	FINAL TEMP 7	0.665	0.693	0.556	0.410	0.801	0.248	0.923
19	COOL TIME	-0.130	-0.134	-0.121	-0.100	-0.168	-0.038	-0.183
20	DELTA TEMP 1	-0.192	-0.183	-0.167	-0.165	-0.140	0.408	0.305
21	DELTA TEMP 2	-0.252	-0.231	-0.295	-0.314	-0.121	0.090	0.461
22	DELTA TEMP 3	-0.240	-0.223	-0.293	-0.328	-0.107	0.076	0.456
23	DELTA TEMP 5	-0.216	-0.199	-0.261	-0.292	-0.104	0.144	0.458
24	DELTA TEMP 6	-0.184	-0.177	-0.210	-0.263	-0.109	0.250	0.414
25	DELTA TEMP 7	-0.284	-0.266	-0.340	-0.356	-0.162	0.008	0.381
26	RATE TEMP. RISE 1	-0.392	-0.384	-0.360	-0.360	-0.353	0.078	-0.184
27	RATE TEMP. RISE 2	-0.498	-0.470	-0.545	-0.567	-0.340	-0.309	0.041
28	RATE TEMP. RISE 3	-0.467	-0.446	-0.527	-0.565	-0.311	-0.278	0.077
29	RATE TEMP. RISE 5	-0.459	-0.434	-0.514	-0.547	-0.321	-0.223	0.039
30	RATE TEMP. RISE 6	-0.396	-0.386	-0.433	-0.520	-0.312	-0.109	-0.032
31	RATE TEMP. RISE 7	-0.457	-0.437	-0.517	-0.525	-0.332	-0.265	0.065
32	STROKES/MIN	-0.303	-0.322	-0.170	-0.130	-0.412	0.197	-0.385
33	INVERSE TIME	-0.099	-0.095	-0.089	-0.112	-0.123	-0.378	-0.528
34	ROOT TIME	0.115	0.115	0.101	0.105	0.141	0.444	0.612
35	SQR TIME	0.117	0.120	0.097	0.081	0.130	0.329	0.476
36	INVERSE ROOT TIME	-0.103	-0.099	-0.092	-0.111	-0.127	-0.415	-0.573
37	INVERSE SQR TIME	-0.095	-0.092	-0.086	-0.110	-0.117	-0.293	-0.425

Leveler Bar Study
Correlation Matrix for Full Model - Heat-up Data

TABLE 27 (continued)

		15	16	17	18	19	20	21
15	FINAL TEMP 3	1.000						
16	FINAL TEMP 5	0.938	1.000					
17	FINAL TEMP 6	0.798	0.918	1.000				
18	FINAL TEMP 7	0.948	0.807	0.817	1.000			
19	COOL TIME	-0.191	-0.170	-0.145	-0.174	1.000		
20	DELTA TEMP 1	0.294	0.303	0.351	0.260	-0.025	1.000	
21	DELTA TEMP 2	0.423	0.300	0.247	0.453	-0.092	0.696	1.000
22	DELTA TEMP 3	0.445	0.313	0.243	0.480	-0.103	0.711	0.977
23	DELTA TEMP 5	0.446	0.365	0.308	0.438	-0.087	0.753	0.947
24	DELTA TEMP 6	0.395	0.354	0.397	0.351	-0.078	0.784	0.843
25	DELTA TEMP 7	0.374	0.213	0.140	0.461	-0.038	0.636	0.927
26	RATE TEMP. RISE 1	-0.161	-0.152	-0.128	-0.146	0.154	0.672	0.254
27	RATE TEMP. RISE 2	0.025	-0.138	-0.232	0.140	0.006	0.375	0.718
28	RATE TEMP. RISE 3	0.089	-0.079	-0.185	0.195	-0.012	0.443	0.729
29	RATE TEMP. RISE 5	0.060	-0.053	-0.149	0.125	0.033	0.474	0.665
30	RATE TEMP. RISE 6	-0.019	-0.084	-0.043	-0.000	0.041	0.459	0.479
31	RATE TEMP. RISE 7	0.068	-0.112	-0.200	0.210	0.039	0.392	0.699
32	STROKES/MIN	-0.395	-0.209	-0.133	-0.482	0.089	0.118	-0.154
33	INVERSE TIME	-0.475	-0.470	-0.489	-0.417	0.101	-0.517	-0.631
34	ROOT TIME	0.559	0.554	0.585	0.481	-0.103	0.637	0.731
35	SQR TIME	0.448	0.450	0.461	0.380	-0.065	0.482	0.534
36	INVERSE ROOT TIME	-0.517	-0.512	-0.537	-0.451	0.105	-0.579	-0.693
37	INVERSE SQR TIME	-0.383	-0.377	-0.387	-0.345	0.094	-0.384	-0.488

		22	23	24	25	26	27	28
22	DELTA TEMP 3	1.000						
23	DELTA TEMP 5	0.966	1.000					
24	DELTA TEMP 6	0.858	0.904	1.000				
25	DELTA TEMP 7	0.950	0.877	0.740	1.000			
26	RATE TEMP. RISE 1	0.295	0.317	0.333	0.283	1.000		
27	RATE TEMP. RISE 2	0.702	0.629	0.475	0.735	0.421	1.000	
28	RATE TEMP. RISE 3	0.768	0.697	0.546	0.783	0.469	0.957	1.000
29	RATE TEMP. RISE 5	0.705	0.717	0.573	0.683	0.561	0.884	0.933
30	RATE TEMP. RISE 6	0.516	0.540	0.697	0.463	0.539	0.608	0.659
31	RATE TEMP. RISE 7	0.722	0.626	0.463	0.839	0.368	0.901	0.920
32	STROKES/MIN	-0.152	-0.074	-0.014	-0.185	0.385	-0.016	-0.031
33	INVERSE TIME	-0.596	-0.622	-0.591	-0.506	0.045	-0.174	-0.221
34	ROOT TIME	0.697	0.741	0.749	0.584	-0.015	0.125	0.170
35	SQR TIME	0.519	0.578	0.593	0.433	-0.043	-0.005	0.029
36	INVERSE ROOT TIME	-0.655	-0.686	-0.667	-0.554	0.027	-0.176	-0.223
37	INVERSE SQR TIME	-0.459	-0.477	-0.437	-0.396	0.092	-0.139	-0.185

		29	30	31	32	33	34	35
29	RATE TEMP. RISE 5	1.000						
30	RATE TEMP. RISE 6	0.729	1.000					
31	RATE TEMP. RISE 7	0.810	0.533	1.000				
32	STROKES/MIN	0.114	0.166	-0.121	1.000			
33	INVERSE TIME	-0.190	-0.128	-0.240	0.303	1.000		
34	ROOT TIME	0.147	0.138	0.175	-0.208	-0.835	1.000	
35	SQR TIME	0.018	0.043	0.044	-0.130	-0.461	0.836	1.000
36	INVERSE ROOT TIME	-0.195	-0.146	-0.234	0.275	0.985	-0.913	-0.573
37	INVERSE SQR TIME	-0.144	-0.074	-0.226	0.346	0.955	-0.671	-0.302

		36	37
36	INVERSE ROOT TIME	1.000	
37	INVERSE SQR TIME	0.893	1.000

APPENDIX D

EMISSION DATA

OBSERVATION PROCEDURE

The basis for evaluation of charging with respect to emissions was the Ringelmann code. This method was selected since most government air pollution regulations are based on the Ringlemann Number or the equivalent opacity. The readings of smoke classification were defined so that a direct comparison could be made with the local air polution control requirements. The time of emissions, classified by opacity (T0, T1, T2, T3), the charging time, and the charge cycle time were recorded using 5 stop watches mounted on a multiple timer board. The recorded parameters are defined in the glossary.

The observation was made at a distance of approximately 50 feet from the charging car with the observer positioned at the south end towards the quench tower. If the wind was coming from the south, then the observation was made from the north end of the car.

RECORDING PROCEDURE

In recording the various Ringlemann times, the principal source of emissions was noted by giving the charging hole number (between ring and drop sleeve), or by noting the hopper (H) if it leaked through the butterfly valve. If the T_3 emissions exceeded #3 Ringlemann, this was noted.

The steam pressure and temperature were read at the 4" header. A "high" ascension pipe represented one of the new design "C" goosenecks while "low" represents the existing design "A" type. In evaluating the condition of the ascension pipe, the upper portion of data sheet represents the gooseneck condition, and the lower part represents the standpipe.

The charging hole data indicates (at left side) proper seating of drop sleeve if "OK" is noted. The data on the right represents the flare carbon condition. The comments for the lid

OBSERVATION PROCEDURE (continued)

represent the quantity of smoke leakage, and also how long it took to seal. The general comments usually indicate the gap between the drop sleeve and the charging hole ring, if the seating was not proper before start of the charge.

DATA SHEETS

The following data sheets are attached.

1. Results of charging 19 ovens on 1-29-73
2. Results of charging 10 ovens on 12-13-73 (corresponds to data in table 3) including stop watch event data.
3. Results of charging 10 ovens on 1-10-74 with 8.3% moisture (corresponds to data in table 4) including stop watch event data.
4. Results of charging over 1-1 or 1-2 during February 1974 using jumper pipes (corresponds to part of data shown in table 5) including stop watch event data.

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder SZCZEPANSKI Date 1-29-73

Time Start ______ Time Finish ______

	10:52	11:03	11:12	11:23	11:46
Ringelmann Time Factor	Oven Number				
	3-23 M	1-25 M	2-25 M	3-25 M	1-27 M
	Time				
T0	14	28	57	12	7
T1	2:00/#2 & 3 H	1:59/#1 & 2 H	1:25/#1&2&3 H	1:52/# 2 & 3	2:46/#2 & 3 H
T2				:25/#3 H	:02/#3 H
T3	:47/#2 & 3 H Over 3*	:25/#2 H Under 3	:46/#2 & 3 H Under 3	:18/1 & 2 H Over 3*	:11/#2 & 3 H Over 3*
Principal Source of Emissions	#2 and 3 Hopper	#2 Hopper	#2 and 3 Hopper	#1 and 2 Hopper	#2 & 3 Hopper
Charging Time	2:15	2:12	2:22	2:04	2:19
Charg Cycle Time	3:01	2:52	3:08	2:47	3:06
Steam Pressure	134	134	134	134	134
Steam Temperature	500	500	500	500	500
Type Ascension Pipe	High	Low	Low	High	Low
Condition of Ascension Pipe	Norm	Const.	Norm	Norm	Const.
	Norm.	Norm	Norm	Const	Norm
Oven Port Seals					
#1 Charging Hole	OK/Light	OK/Med.	OK/X Heavy	OK/X Heavy	OK/X Heavy
#2 Charging Hole	1/Med.	OK/X HEAVY	OK/Med.Heavy	OK/X HEavy	OK/Med.Heavy
#3 Charging Hole	OK/Heavy	OK/ Med.	OK/ Light	/ Med.	OK/ Med.
Ascension Pipe Lid	OK	Light 5 Min.	Light 5 Min.	OK	Med. 5 To 10Min.
Smoke Seal and Leveler Door	P-4	P-4	P-4	P-4	P-4
Gen'l.Comments on Oven Seals				#3 DR 1 1/2 in.	
Drop Sleeve Seating	#2 DR 3 1/2 in.				
	* #2 & 3, While lidding #1 & #2	#2 & 3 While lidding #1 & #2	While lidding #1 & #2 H	While lidding #1 & #2 H	While lidding #1 & #2 H

CHARGING CYCLE OvEN EMISSION DATA SHEET

Recorder Szczepanski

Date

Time Start

Time Finish

	11:55	1:10	1:19	1:31	1:46
Ringelmann Time Factor	Oven Time				
	2-27 M	3-2 M	1-4	2-4	3-4
TO	Time				
	43	10	16	27	45
T1	1:39/ #2 & 3	1:40/ #1-2-3 H	2:44/ #2 & 3	1:03/ #1 & 3	1:03/ #1 & 3
T2	:13/ #2	:29/ #2	:51/ #2H	:15/ #1	:10/ #2
T3	:16/ #2 Over 3*	:51/ #1-2-3H Over 3*	:53/ #2H Over 3*	:54/ #3 Over 3*	:51/ #3 Over 3*
Principal Source of Emissions	#2 H	#3H	#2 H	#3 H	
Charging Time	2:10	2:20	2:50	1:48	1:58
Charg Cycle Time	2:51	3:10	4:44	2:39	2:49
Steam Pressure	134	134	134	134	134
Steam Temperature	500	500	500	500	500
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe	Norm Norm	Norm Norm		Norm Norm	Const. Norm
Oven Port Seals					
#1 Charging Hole	OK/ Med. Heavy	OK/ X Heavy	OK/ Heavy	OK/ Med.	OK/ Med.
#2 Charging Hole	OK/ Heavy	OK/ XX Heavy	OK/ X Heavy	OK/ X Heavy	OK/ Med.
#3 Charging Hole	/ Light	/ Med.	OK/ XX Heavy	OK/ Heavy	OK/ Light
Ascension Pipe Lid	Light 5 Min.	Med. 5 to 10 Min.	Med. 5 Min.	OK	Heavy 5 to 10 Min.
Smoke Seal and Leveler Door	P-4	P-4	P-4	P-4	P-4
Gen'l. Comments on Oven Seals	#3 RS 1½ in.	#3 RS 1 in.		#3 RS 1½ in.	
	While Lidding #1 & 2 H	#3 Ran Emptv also while lidding 1-2-[illegible]	#2 Ran Empty also while lidding #1 & 2H	*#3 Ran Empty	*#3 Ran Empty

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder Szczepanski

Date

Time Start

Time Finish

		2:07	2:17	2:27	2:36
Ringelmann Time Factor	Oven Time				
	1-6	2-6	1-6	1-8	2-8
	Time				
T0	15	29	61	63	
T1	2:09/#1 & 3	1:31/#1 & 3H	2:31 /#1 & 3	1:47/#1-2-3H	
T2		:25/ #1	:48/ #2 & 3		
T3	1:32/ #3 Over 3*	:55/ #2 & 3 Over 3*	:09/ #3H Over 3*	:35/ #3 Over 3*	
Principal Source of Emissions	#3	#2	#3H	#2 & 3H	
Charging Time	3:02	2:10	3:51	2:30	
Charg Cycle Time	3:56	3:20	4:29	3:25	
Steam Pressure	170	170	170	170	
Steam Temperature	510	510	510	510	
Type Ascension Pipe	Low	Low	Low	Low	
Condition of Ascension Pipe	Norm Norm	Const. Norm	Norm Const.	Norm --	
Oven Port Seals					
#1 Charging Hole	OK/XX Heavy	OK/Heavy	OK/Heavy	OK /X Heavy	
#2 Charging Hole	OK/X Heavy	OK/XX Heavy	OK/Med.	OK/XX Heavy	
#3 Charging Hole	OK/Heavy	OK/Med.	OK/Light	OK/Heavy	
Ascension Pipe Lid	Heavy 5 to 10 Min.	Med. 5 Min.	Light 5 to 10 Min.	Light 5 to 10 Min.	
Smoke Seal and Leveler Door	Heavy Smoke 1:15 out of C.D.	P-4	P-4	P-4	
Gen'l.Comments on Oven Seals	--	1 ½ on RS #3	#3 RS 1 in.	#3 RS 1 in.	
	* After 80% also while lidding 1 2 & 3	While lidding #1 2 3	While lidding #2	While lidding #2 and 3	

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder Szczepanski Date

Time Start Time Finish

	2:46	2:52	3:06	3:14	3:25
Ringelmann Time Factor	Oven Time				
	3-8	1-10	2-10	3-10	1-12
T0	Time				
	26	21	15	69	9
T1	:59/ #2 & 3	1:52/ #2 & 3	3:05/ #2 & 3	1:14/ #1, 3	2:23/ #2 & 3
T2	1:16/ #2	:40/ #2 & 3	:07 #2 when /1st charge began	--/ --	:02/ #1
T3	:21/ #3 Under 3	:26/ #2 & 3 Under 3	--/ -- *	:48/ #3 Over 3*	:31/ #1 Under 3
Principal Source of Emissions	#2H	#2 & 3H	#2 & 3	#3	#1
Charging Time	2:12	2:32	2:43	2:16	2:22
Charg Cycle Time	3:02	3:19	3:27	3:11	3:05
Steam Pressure	170	170	170	170	170
Steam Temperature	510	510	510	510	510
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe	Const. Norm	Norm Norm	Const. Norm	Norm Norm	Norm Norm
Oven Port Seals					
#1 Charging Hole	OK/ Heavy	OK/ Med.	OK/ X Heavy	OK/ Heavy	OK/ Med.
#2 Charging Hole	OK/ Med.	OK/ XX Heavy	/ XX Heavy	OK/ X Heavy	OK/ Med.
#3 Charging Hole	OK/ Med.	OK/ Med.	OK/ Med.	/ Med.	/ Med.
Ascension Pipe Lid	Light 5 Min.	Heavy 5 to 10 Min.	Light 5 Min.	Heavy 10 to 15 Min	Light 5 Min.
Smoke Seal and Leveler Door	P-4	P-4	P-4	P-4	P-4
Gen'l.Comments on Oven Seals	2 in.RS #3	1½ in. RS	4 in UR #2 Hit Lid	#3 UR 1 in.	1½ in. RS

#2 Lite OFF

While lidding #1 & 2

CHARGING CYCLE OVEN EMISSION DATA SHEET

Date January 29, 1973

Weather Conditions	
Ambient Temperature	30°
Atmospheric Condition	OVER CAST
Wind Velocity and Direction	N N W 6 mph.
Atmospheric Pressure	29.62
Precipitation	SNOW SHOWERS
Humidity	84%
	Daily Coal Analysis (Lab Record)
Weight Per Cubic Foot	43.10
% Volatile Matter	32.26
% Moisture	7.00
% Fixed Carbon	59.89
% Ash	7.85
% Sulfur	1.22
Oil Pints/ton coal	3.38

Comments on Data: (includes equipment malfunctions)

Conclusions:

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder John DeFrances **Date** 12-13-73

Time Start 1:30 **Time Finish** 3:30

Ringelmann Time Factor	Oven Number				
	3-9	1-11	2-11	3-11	1-13
	Time				
T_0	63	71	74	92	44
T_1	90	63	54	126	95
T_2	89	49	141	39	37
T_3	0	37*	30	15	84*
Principal Source of Emissions					
Charging Time	174	105	168	147	155
Charge Cycle Time	242	220	299	272	260
Steam Pressure	125	125	125	125	125
Steam Temperature					
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe					
Oven Port Seals					
#1 Charging Hole	OK/Lite	OK/Lite	OK/Med.	OK/Lite	OK/Lite
#2 Charging Hole	OK/Lite	OK/Lite	OK/Med.	OK/Lite	OK/Med.
#3 Charging Hole	OK/Med.	OK/Lite	OK/Lite	OK/Lite	OK/Lite
Ascension Pipe Lid	Lite - 5'	Med.-10'		Lite - 5'	Lite 5-10'
Smoke Seal and Leveler Door	P-4	P-4	P-4	P-4	P-4
Gen'l Comments on Oven Seals					

* T3 Emissions exceeded #3 part of the time.

Charge cycle time recorded as ending with the lid on #3 charging hole

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder John DeFrances **Date** 12-13-73

Time Start 1:30 **Time Finish** 3:30

Ringelmann Time Factor	Oven Number				
	2-13	3-13	1-15	2-15	3-15
	Time				
T0	21	35	87	68	25
T1	124	125	99	86	62
T2	43	66	176	91	96
T3	104*	39*	34*	50*	37*
Principal Source of Emissions					
Charging Time	174	171	270	162	114
Charge Cycle Time	292	265	396	295	220
Steam Pressure	125	125	125	125	125
Steam Temperature					
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe					
Oven Port Seals					
#1 Charging Hole	OK/ Lite	OK/ Med.	OK/ Med.	OK/ Lite	OK/ Med.
#2 Charging Hole	OK/ Med.	OK/ Med.	OK/ Lite	OK/ Med.	OK/ Hvy.
#3 Charging Hole	OK/M.Hvy.	OK/Med.	OK/M.Hvy.	OK/Lite	OK/Med.
Ascension Pipe Lid	Lite 5-10'	Med.5-10'	Lite 5-10'	Med. 10-15	--
Smoke Seal and Leveler Door	P-3	P-3	P-3	P-3	P-3
Gen'l Comments on Oven Seals			Coal Woundn't run out #3 Hopper		

* T3 Emissions exceeded #3 part of the time.

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER J. H. Stoltz DATE 12-13-73

Oven No.		3-9	1-11	2-11	3-11	1-13
Time Start Charge		1:40	1:49	1:58	2:08 start 1 & 2 10 sec. late	2:17 Approx. Times start #1,2 0.25 min. later
Time Reach 80% Empty	Hopper 1	1.0	1.05	1.15	1.03	1.35
	2	0.95	0.90	0.95	1.2	1.2
	3	1.05	1.00	1.85	1.7	1.15
Time Start Level		1.05	1.0	1.0	1.05	1.2
Time Open Butterflies	Hopper 1	1.15	1.10	1.9	1.75	1.4
	2	1.15	1.10	1.9	1.75	1.4
	3	1.15	1.10	1.9	1.75	1.4
Time Hoppers Empty	Hopper 1	1.5	1.4	2.35	2.1	1.8
	2	1.7	1.75	2.5	2.45	2.35
	3	1.9	1.7	2.8	2.45	1.95
Time Request Stop Level and Close Chuck Door		2.35	2.25	3.2	3.0	2.8
Time Chuck Door Closed		3.3	2.90	4.2	4.0	3.6
Time Start Relid	Hopper 1	3.2	2.95	4.25	3.75	3.65
	2	3.6	3.20	4.45	4.0	3.85
	3	3.85	3.45	4.65	4.30	4.10
Time Steam Off		4.25	4.0	5.1	4.7	4.55
Did Swab go in Gooseneck		NO	YES	YES	NO	YES
% Open Standpipe		80%	70%	90%	100%	75%
Comments	complete damper off	4.90	4.60	5.8	5.35	5.5
	start coal fill	6.20	5.40	7.3	6.4	6.3
	coal fill done	6.90	6.30	8.1	7.3	7.2
	Start clean G.N. of next oven	7.50	7.0	9.1	7.8	8.1
	Spot car next oven to chg	8.40	8.1	9.8	8.5	9.2

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER J. H. Stoltz DATE 12-13-73

USES P-3 PUSHER MANUAL LEVEL

Oven No.		2-13	3-13	1-15	2-15	3-15
Time Start Charge		2:37 start #1,2 15 sec later	2:47 start #1,2 15 sec later	2:58 start #1,2 15 sec later	3:07 0.60 min. later start 1&2	3:17 Approx. Times 10 sec. later start 1,2
Time Reach 80% Empty	Hopper 1	1.25	1.45	1.4	1.8	1.1
	2	1.05	1.2	1.3	1.5	1.0
	3	1.20	1.1	3.0	1.7	1.05
Time Start Level		1.0	1.15	1.3	1.5	1.05
Time Open Butterflies	Hopper 1	1.25	1.45	3.0	1.8	1.1
	2	1.25	1.45	3.0	1.8	1.1
	3	1.25	1.45	3.0	1.8	1.1
Time Hoppers Empty	Hopper 1	1.9	2.85	3.2	2.2	1.5
	2	2.4	1.8	3.5	2.7	1.9
	3	2.9	2.85	4.5	2.6	1.6
Time Request Stop Level and Close Chuck Door		3.4	3.3	4.5	3.2	2.4
Time Chuck Door Closed		4.5	4.75	5.2	4.1	3.3
Time Start Relid	Hopper 1	4.1	4.0	6.0	4.1	3.0
	2	4.25	4.2	6.2	4.4	3.2
	3	4.7	4.4	6.4	4.7	3.4
Time Steam Off		5.0	4.75	6.75	5.0	3.7
Did Swab go in Gooseneck		YES	NO	YES	YES	YES
	% open stand pipe	80%	50%	50%	85%	70%
Comments	Complete damper off	5.6	5.5	7.4	5.6	Not recorded
	Start coal fill	6.65	6.8	8.2	6.5	Not recorded
	Coal fill done	7.6	8.15	9.0	7.2	Not recorded
	Start cln.G.N of next oven	8.65	9.0	9.8	8.5	Not recorded
	Spot car next oven to chg.	9.45	9.5	10.2	9.3	

CHARGING CYCLE OVEN EMISSION DATA SHEET

Date 12-13-73

Weather Conditions	
Ambient Temperature	$41^{\circ}F$
Atmospheric Condition	Overcast - Had been raining just previous to taking test data.
Wind Velocity and Direction	S.E. 5 mph
Atmospheric Pressure	29.14
Precipitation	None
Humidity	85%

Daily Coal Analysis (Lab Record)

Weight Per Cubic Foot	42.78
% Volatile Matter	32.22
% Moisture	7.06
% Fixed Carbon	60.91
% Ash	6.87
% Sulfur	1.21
Oil pints/ton coal	2.5 - 2.9 pints/ton

Comments on Data: (includes equipment malfunctions)

Pulverization	% on 3/4"	0%
	on 1/2"	1.0
	on 1/4"	6.5
	on 1/8"	17.7
	thru 1/8"	74.8

Conclusions:

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder D. Cipallone Date 1-10-74

Time Start 11:00 Time Finish 12:00

Ringelmann Time Factor	Oven Number				
	2-21	3-19	3-21	1-23	2-23
	Time				
T_0	0:13	0:04	0:03	0:43	1:15
T_1	0:33	3:11	2:13	1:41	0:17
T_2	0:30	0:50	0:50	0:36	0:49
T_3	3:12	0	2:09	0:03	0:42
Principal Source of Emissions	#3+2 hopper	3+2 hopper	3+2 hopper	3 +2 hopper	3 +2 hopper
Charging Time	3:45	3:40	4:02	2:30	2:20
Charge Cycle Time	4:28	4:05	5:15	3:03	3:03
Steam Pressure	118	121	121	118	118
Steam Temperature					
Type Ascension Pipe	Low	High	High	Low	Low
Condition of Ascension Pipe					
Oven Port Seals					
#1 Charging Hole	Med./OK	Med./OK	Med./OK	Med./OK	Med/OK
#2 Charging Hole	Med./OK	Med./OK	Heavy/OK	Light/OK	Med./OK
#3 Charging Hole	Med./OK	Med./	Light/OK	Light/	Light/OK
Ascension Pipe Lid	Light 5-10	Heavy over 30	Heavy over 30	Heavy over 30	Heavy over 30
Smoke Seal and Leveler Door	4 pusher	4 pusher	4 pusher	4 pusher	4 pusher
Gen'l Comments on Oven Seals		#3Drop Slv. 4" off		#3 Drop Slv.off 1"	
	WE 1:15 Fire 2:28 #7 Hop.	Fire 1:05	WE 3:55	Fire 0:30	WE 2:10

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder D. Cipallone **Date** 1-10-74

Time Start 2:00 **Time Finish** 2:15

Ringelmann Time Factor	Oven Number				
	3-23	1-27	2-2	1-4	2-4
	Time				
T_0	1:33	2:29	2:19	0:17	2:45
T_1	0:29	1:17	1:02	1:56	1:10
T_2	0:27	0:22	0:32	0:46	0:42
T_3	0:51	0:04	0:02	0:56	0:35
Principal Source of Emissions	3+2 hopper	3 hopper		3+2 hopper	
Charging Time	2:50	3:20	2:50	2:47	4:15
Charge Cycle Time	3:20	4:12	3:55	3:55	5:12
Steam Pressure	128	116	116	144	114
Steam Temperature					
Type Ascension Pipe	High	Low	Low	Low	Low
Condition of Ascension Pipe					
Oven Port Seals					
#1 Charging Hole	Med./ OK	Med./ OK	Med./ OK	Med./	Light/ OK
#2 Charging Hole	Med./ OK	Light/ OK	Light/ OK	Light/	Heavy/ OK
#3 Charging Hole	Light/ IK	Light/	Light/ OK	Light/	Heavy/ OK
Ascension Pipe Lid	Med. 20	Medium	Extra Heavy	Heavy	Heavy
Smoke Seal and Leveler Door	#4 Pusher	#4 Pusher	#4 Pusher	#4 Pusher	#4 Pusher
Gen'l Comments on Oven Seals		3 Drop slv off 4"		#2 hopper off 3"	
		#2:25 fire		1:00 Fire WE 2:40	

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER Szczepanski DATE 1-10-74

COAL VERY WET

Oven No.		2-21	3-19	3-21	1-23	2-23
Time Start Charge		11 00	11:10	11:19	11:31	11:39
Time Reach 80% Empty	Hopper 1	2:43	2:24	2:10	1:24	1:10
	2	2:23	2:00	1:48	1:14	51
	3	2:26	1:52	1:40	1:07	55
Time Start Level		2:25	2:07	1:52	1:25	1:00
Time Open Butterflies	Hopper 1	Ran	2:37	2:16	1:40	1:20
	2	Contin.	2:37	2:16	1:40	1:20
	3	--	--	--	--	---
Time Hoppers Empty	Hopper 1	3:00	2:50	2:36	1:53	1:40
	2	3:21	3:20	3:57	2:09	2:03
	3	3:00	2:24	2:24	1:35	1:28
Time Request Stop Level and Close Chuck Door		4:00	3:50	5:00	2:42	2:30
Time Chuck Door Closed		4:40	4:23	5:30	5:20	3:02
Time Start Relid	Hopper 1	3:45	3:40	4:25	2:28	2:20
	2	3:56	3:50	5:00	2:40	2:30
	3	4:10	4:03	4:15	2:53	2:45
Time Steam Off						
Did Swab go in Gooseneck		YES	YES	YES	YES	YES
Comments		Poke 1 shut off 2 & 3 until top lt.of 1 came on	Poke 1 & 2 shut off 3 until 1 & 2 #2 jamb near end	Poke 1 & 2 #2 jamb backed up in hole		

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER Szczepanski DATE 1-10-74

Oven No.		3-23	1-27	2-2	1-4	2-4
Time Start Charge		11:47	1:17	1:37	1:51	2:02
Time Reach 80% Empty	Hopper 1	2:00	2:20	2:07	2:02	2:13
	2	1:37	2:00	1:56	1:56	2:00
	3	1:34	1:56	2:04	2:02	2:01
Time Start Level		1:45	2:05	2:11	2:02	2:00
Time Open Butterflies	Hopper 1	2:11	2:28	2:22	2:19	2:20
	2	2:11	2:28	2:22	2:19	2:20
	3	-	-	-	-	-
Time Hoppers Empty	Hopper 1	2:28	2:43	2:30	2:31	2:35
	2	2:37	3:00	2:52	2:42	4
	3	2:10	2:27	2:37	2:31	2:42
Time Request Stop Level and Close Chuck Door		3:14	3:24	3:25	3:15	4:25
Time Chuck Door Closed		3:51	3:58	4:05	3:55	5:04
Time Start Relid	Hopper 1	2:54	3:30	3:07	2:54	
	2	3:05	3:40	3:25	3:04	
	3	3:16	3:58	3:35	3:40	
Time Steam Off						
Did Swab go in Gooseneck		YES	YES	YES	YES	
Comments		Poke 1	Poke 1& 2 #1 Lid did not go on		1	Poke 2

CHARGING CYCLE OVEN EMISSION DATA SHEET

Date 1-10-74

Weather Conditions	
Ambient Temperature	35°F
Atmospheric Condition	Over Cast
Wind Velocity and Direction	From N. - N.E. 5 mph
Atmospheric Pressure	29.97
Precipitation	Intermittent Rain
Humidity	89%

Daily Coal Analysis (Lab Record)

Weight Per Cubic Foot	41.49
% Volatile Matter	32.22
% Moisture	9.26%
% Fixed Carbon	60.44%
% Ash	7.34%
% Sulfur	1.21
Oil pints/ton coal	

Comments on Data: (includes equipment malfunctions)
Pulverization

Conclusions:

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder D. Cipollone

Date 1-10-74 to 2-22-74

Time Start

Time Finish

	1-10-74	2-14-74	2-15-74	2-21-74	2-22-74
Ringelmann Time Factor	Oven Number				
	1-2	1-2	1-1	1-2	1-1
	Time				
T_0	3:36	3:04	3:45	3:14	2:57
T_1	0:21	0:14	0:08	0:08	0:07
T_2	0:06	0	0	0	0
T_3	0 :04	0 :02	0 :02	0 :03	0 :02
Principal Source of Emissions	3 hopper		#1 hopper @ 1:55	#2 & #3	#1 & #2
Charging Time	3:00	2:45	2:30	2:18	2:21
Charge Cycle Time	4:07	3:20	3:35	3:25	3:06
Steam Pressure	109	125	127	116	130
Steam Temperature *	-	-	-	-	-
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe	?	100%	95%	95%	95%
Oven Port Seals					
#1 Charging Hole	OK/ Med.	OK Med.	OK/ Light	OK/ Med.	OK/ Med.
#2 Charging Hole	OK/ Med.	OK/ Med.	OK/ Med.	OK/ Med.	OK/ Hvy.
#3 Charging Hole	No/ Light	OK Med.	OK/ Med.	OK/ Med.	OK/ Light
Ascension Pipe Lid	Heavy	Med. 5 min.	Light	Light	Light
Smoke Seal and Leveler Door	#4 Pusher used	#4	#4	#4	#4
Gen'l Comments on Oven Seals	#3 Drop slv.off hole for 25 seconds	--	Fire #2 hopper @ 2:05	Emissions at 1:00 2 sec. 1:40 2 sec. 1:58 4 sec.	Emissions at 1:50 6 sec. 2:05 1 sec.

* Approximately 450°F

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER Szczepanski DATE 1-10-74 to 2-22-74

Oven No.		1-10-74 1-2	2-14-74 1-2	2-15-74 1-1	2-21-74 1-2	2-22-74 1-1
Time Start Charge		(1:29 pm) 0	0	Started 2 after top level lite on for #1& #2	Timing Data not Taken. Relidded all Charging Holes Prior to the Leveler Door being Shut.	
Time Reach 80% Empty	Hopper 1	1:45	?	1:15		
	2	1:45	1:00	1:15		
	3	1:40	1:05	1:10		
Time Start Level		1:45	1:10	1:20		
Time Open Butterflies	Hopper 1	2:20	1:15	1:25		
	2	2:20	1:15	1:25		
	3	--	1:15	1:25		
Time Hoppers Empty	Hopper 1	3:00	2:55	2:15		
	2	3:10	2:10	2:30		
	3	3:00	2:15	2:35		
Time Request Stop Level and Close Chuck Door		3:50				
Time Chuck Door Closed		4:40	3:00	3:15		
Time Start Relid	Hopper 1	3:45	3:05	3:20		
	2	3:15	2:15	2:45		
	3	3:35	2:45	3:20		
Time Steam Off		--				
Did Swab go in Gooseneck		Yes				
Comments		Poke #2 Drop slv.	#1 Butterfly jammed	Top Level lites show coal has started out of hopper		

CHARGING CYCLE OVEN EMISSION DATA SHEET

Recorder D. Cipottone

Date 3-5-74 to 3-25-74

Time Start

Time Finish

	3-5-74	3-6-74	3-15-74	3-18-74	3-25-74
Ringelmann Time Factor	Oven Number				
	1-1	1-2	1-1	1-1	1-2
T_0	Time				
	3:39	3:11	1:49	3:53	3:05
T_1	0:02	0:04	0:05	0:06	0:07
T_2	0:00	0:00	0:12	0:07	0:03
T_3	0:04	0:05	0:09	0:03	
Principal Source of Emissions	#1, #3 Sleeve	#1, #2 Sleeve	#1, #3 D. Sleeve	#2 Sleeve	#2 Drop Sleeve
Charging Time	2:30	2:29	1:50	3:45	2:05
Charge Cycle Time	3:45	3:20	2:20	4:09	2:45
Steam Pressure	124	140	136	132	130
Steam Temperature					
Type Ascension Pipe	Low	Low	Low	Low	Low
Condition of Ascension Pipe	80%	95%	85%	80%	100%
Oven Port Seals					
#1 Charging Hole	Med/OK	Med/OK	Med/OK	Med/OK	Med/OK
#2 Charging Hole	Hvy/OK	Med/OK	Hvy/OK	Med/OK	Med/OK
#3 Charging Hole	Med/OK	Med/OK	Med/OK	Med/OK	Med/OK
Ascension Pipe Lid	Light	Light	Light	Light	Heavy
Smoke Seal and Leveler Door	#4 Pusher	#4 Pusher	#4 Pusher	#4 Pusher	#4 Pusher
Gen'l Comments on Oven Seals		1:15 #1 1:50 #1 2:05 #1 2:15 #2	0:30 #1 10:05 #3 1:35 #2,3 1:50 #1	0:10) #1,3 0:15) Sleeve 2:00 #1,2 2:15 #2	T_1 + T_2 #2 D.S. 1:30 T_1 #2 D.S. 2:00

CHARGING CYCLE OVEN EMISSION DATA SHEET

RECORDER Szczepanski DATE 3-5-74 to 3-25-74

Oven No.		3-5-74 1-1	3-6-74 1-2	3-15-74 1-1	3-18-74 1-1	3-25-74 1-2
Time Start Charge		0	0	0	0	0
Time Reach 80% Empty	Hopper 1	1:05	1:00	1:00	1:00	1:00
	2	0:55	1:00	1:08	1:00	0:55
	3	1:15	1:05	1:00	1:15	0:55
Time Start Level		1:25	1:05	1:00	1:00	1:00
Time Open Butterflies	Hopper 1	1:35	1:35	1:30	1:45	1:20
	2	1:35	1:35	1:30	2:30	1:20
	3	1:35	1:35	1:30	3:10	1:20
Time Hoppers Empty	Hopper 1	2:03	2:20	1:51	2:10	1:55
	2	2:04	2:00	1:46	2:55	1:50
	3	2:05	2:03	1:51	3:40	1:45
Time Request Stop Level and Close Chuck Door						
Time Chuck Door Closed		3:00				2:35
Time Start Relid	Hopper 1	3:00	2:30	1:55	2:15	2:05
	2	3:10	2:40	2:05	3:00	2:10
	3	3:35	2:55	2:15	3:50	2:15
Time Steam Off						
Did Swab go in Gooseneck						
Comments						

Daily Coal Analysis

Date	WT/FT^3	% Vol. Matter	% Moisture	% Fixed Carbon	% Ash	Oil PTS/Ton Coal
1-10	41.49	32.22	8.26	60.44	7.34	2.69
2-14	39.86	32.28	8.09	60.38	7.18	1.20
2-15	42.71	32.28	7.55	60.35	7.27	1.20
2-21	42.99	32.27	8.50	60.48	7.25	1.81
2-22	43.40	32.26	8.03	60.56	7.18	2.50
3-5	41.66	32.26	7.56	60.63	7.11	2.43
3-6	39.58	32.23	8.00	60.39	7.38	1.87
3-15	41.85	32.26	8.49	60.65	7.09	?
3-18	42.36	32.23	8.00	60.45	7.33	?
3-25	42.08	32.24	8.54	60.51	7.25	2.44

APPENDIX E

EMPTY OVEN TESTS

The procedure used to estimate the ascension pipe gas flow as a function of steam ejector thrust and steam pressure was fully described in a previous report on this work[9]. That procedure is outlined here. The test arrangement is shown on Figure 50 (pg.157). Details of the special orifice flow meter are shown in Figure 75.

In the test work on P-4 battery high pressure, super heated steam (200 psig, 500°F) was supplied from an auxiliary 4" header. A 1" line connected the steam nozzle to the 4" header. A pressure regulator was connected in the 1" line near the header.

A test run consisted of taking vacuum measurements with different size steam nozzles at different steam pressures. The values of oven vacuum, flow meter differential pressure, steam pressure, and steam temperature recorded during the test were used to calculate the nozzle and air flow rates. The method of best fit was used to determine the performance curves for each trial. The average performance curve was computed using the best fit curve for each test and calculating the average values.

Thrust was used as the independent variable because it is a good indication of input energy.

METHOD OF CALCULATION

Mass Flow of Steam

$$W_s = 0.3155\ (A_t)\sqrt{\frac{P_1}{V_1}}$$

From Kent's
Mechanical Engineers
Handbook - 8 - 18

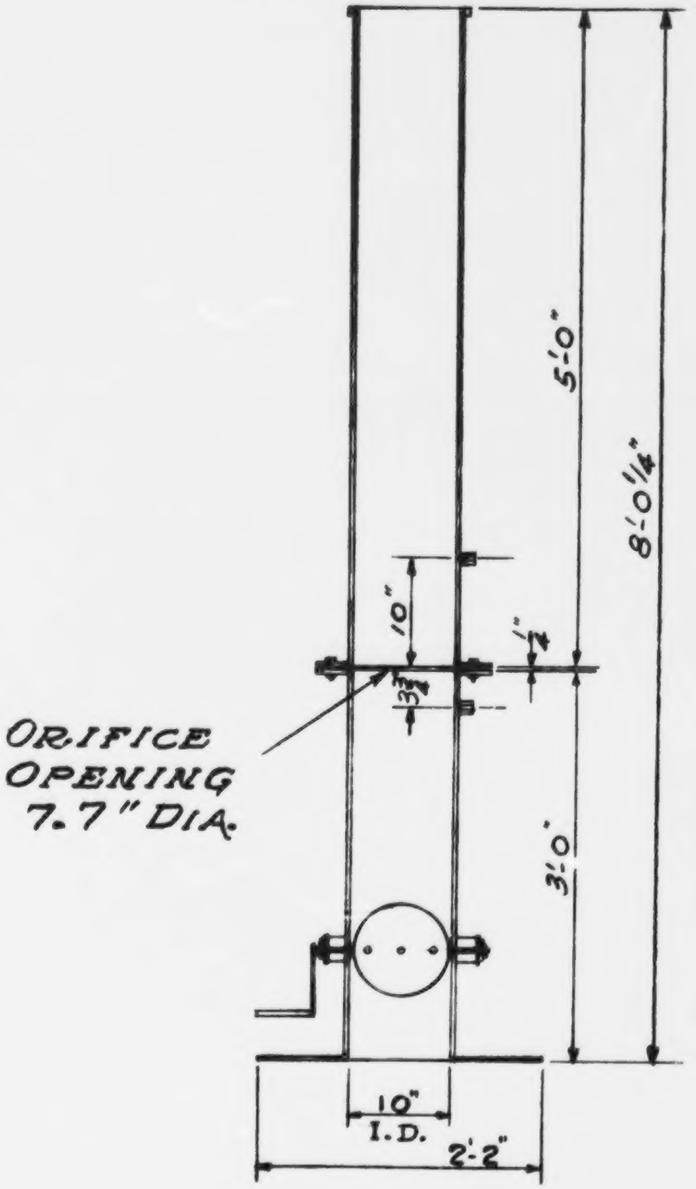
W_s = Pounds of superheated steam per second

A_t = Area of throat - In.^{2}

P_1 = Initial pressure - PSIA

V_1 = Specific volume - Ft.^{3}/lb. at P_1 and T_1

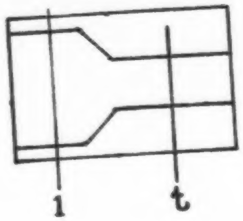
ORIFICE FLOW METER
CROSS SECTION



5'0"
8'0¼"
10"
½"
3¾"
ORIFICE OPENING 7.7" DIA.
3'0"
10" I.D.
2'2"

Figure 75

METHOD OF CALCULATION (continued)



Nozzle Thrust

$$F = P_t A_t + \frac{W_s V_t}{g_c}$$

From: Elements of Fluid Mechanics by D.G.Shepherd. 1965. Harcourt, Brace and World Inc., New York

Assume: P_1 and T_1 are stagnation values ($V_1 = 0$)

P_t = Pressure at the throat = $0.55\ P_1$ - PSIA

A_t = Area of throat - $In.^2$

W_s = Flow of steam - lb/sec.

g_c = Constant = 32.2

H_1 = Enthalpy at initial conditions

H_t = Enthalpy at the throat conditions (This value is taken from a Mollier Chart)

V_t = Velocity of steam at the throat

$$= \sqrt{2\ g_c\ (H_1 - H_t)(778.3)}\ \text{Ft/Sec.}$$

Air Flow Rate

$$Q = C \cdot D^2 \cdot H_1 \cdot P \cdot T \cdot S \cdot M \cdot B \cdot X$$

From: Flow Meter Engineering Handbook by the Brown Insititute Co.

METHOD OF CALCULATION (continued)

Air Flow Rate (continued)

Q = Air Flow Rate - Ft.^3/hr. at 30" Hg, 60°F, dry gas

C = Orifice coefficient of discharge - 0.76

D = Pipe diameter = 10.0 inches

H = Differential pressure across the orifice

H_1 = Differential pressure factor - $\sqrt{H}$

P_o = Atmospheric pressure - 30" Hg

P = Gas pressure factor - $237.1\sqrt{P_o} = 1298.6$

t = Operating temp. °F

T = Gas temperature factor = $\sqrt{519.63/(459.63 + t)}$

S = Specific gravity factor = 1.0

M = Moisture factor = 1.0

B = Gas base factor - 1.0

X = Flow meter correction factor based on calibration done by the Colorado Engineering Experimental Station - = 0.15H + 0.54 Up to X= 0.7

TEST PROCEDURE

The following describes the work required to set up for a typical test run:

1. Charge walkie-talkie batteries the day before the test.
2. Notify all required personnel: Operating, Maintenance and Research.
3. Turn the 8 channel recorder on at least one hour prior to testing.

TEST PROCEDURE (continued)

4. Examine the oven to be tested and clean the gooseneck, the standpipe and the charging holes if necessary. Clean away any carbon near the steam nozzle connection.

5. Make sure oven doors are tight, especially the chuck door.

6. Install the first nozzle to be tested.

7. Install a 1" steam line from the special 4" header to the gooseneck steam nozzle. The line has a pressure regulator, pressure tap, temperature tap, pressure gauge and a quick opening valve.

8. Install the pressure tap in the base of the standpipe.

9. Connect the standpipe pressure tap to a pressure transducer with +2 to -8 inches of H_2O scale range.

10. Install the thermocouple in the base of the standpipe.

11. Connect the standpipe thermocouple to the 8 channel recorder (500 to 2000°F temperature range channel).

12. Connect the steam pressure tap to the 50-200 psi transducer.

13. Install steam temperature thermocouple.

14. Connect steam temperature thermocouple to 8 channel recorder.

15. Install a lid with a pressure tap on the No. 1 charging hole (pusher side). Seal lid with refractory cement.

16. Connect the lid to a pressure transducer with +2 to -8 inches of water scale range.

17. Repeat steps 13 and 14 for charging hole No. 3 and for the smoke hole.

18. Place the flow meter over #2 charging hole, sealing it with asbestos rope between its bottom flange and the oven. Use refractory cement to seal it.

TEST PROCEDURE (continued)

19. Connect the flow meter to one of the differential pressure transducers.

20. Connect all transducers to the 8 channel recorder.

21. Check out all test equipment and calibrate it. Note the weather conditions, the collecting main pressure, and ammonia liquor line pressure.

22. Run the test using the various steam pressures and nozzle sizes required, as described below.

23. After completion of the test dismantle the equipment and store it in the proper areas.

24. Examine recorder chart and take off data.

25. Punch out data cards and make a computer run for calculated data.

After the test apparatus had been set up, the actual test was run according to the following steps for each steam pressure setting:

1. Set the ejector steam pressure.

2. Turn the ejector steam on and open the damper valve.

3. Wait for the readings to stabilize with the butterfly valve closed in the flow meter.

4. Open the butterfly valve and wait until a fairly constant differential pressure across the flow meter orifice is recorded.

5. Be sure all recorder channels are working properly.

6. Close the damper valve, turn off the ejector steam, then repeat for the next pressure.

TEST PROCEDURE (continued)

When all pressure settings were used the nozzle was changed and the above steps were repeated.

TEST EQUIPMENT

Quantity	Description
1	Smoke hole lid with a pressure tap (1/2" pipe)
2	Charging hole lids with pressure taps (1/2"pipe)
1	Pressure tap for the base of the standpipe (1/2" pipe)
1	Thermocouple (Cromel-Alumel) for measuring the gas temperature (0-2000°F) inside of the standpipe
1	Pressure tap for the collecting main
2	Orifice flow meters PSX-5163 (Custom designed for this application - see Figure 75.)
400 feet	3/8" type L copper tubing (soft)
20	Tubing splices 3/8
8	3/8 tubing to 1/2" pipe male thread
8	3/8 tubing to 1/2" pipe female thread
10	3/8 tubing to transducer
1	Thermocouple for measuring steam temperature (Cromel-Alumel)
1	Pressure recorder, ± 15 MM H_2O range
1	Eight channel oscilliograph recorder
2	Differential pressure transducers, 0-50 MM H_2O range

TEST EQUIPMENT (continued)

Quantity	Description	
5	Pressure transducers, +2" to -8" H_2O range	
1	Pressure transducer 50 to 200 psi range	
1	Cart with wheels for eight pressure transducers	
1	Air conditioned (heated and cooled) building 4' x 11' x 8' high, with lifting lugs, to store recorder etc., on battery	
1	Thermometer	for ambient air conditions
1	Humidity measuring device	
1	Pressure regulator with a pressure gauge, 50-200 psi range	
10 feet	1" diameter asbestos rope	
1	Bucket of sealing mud	
3	Steam pressure regulators 25 - 200 psi range	
1	Steam pressure gauge 0-200 psi range	
1	Heise pressure gauge to check steam pressure transducer calibration	
1	Potentiometer for thermocouple checks	
1	Manometer	
*	Assorted pipe fittings and lengths of pipe	
2	Walkie-talkies	

APPENDIX F

BATTERY DIMENSIONAL VARIATIONS

The use of a larry car for mechanized charging depends on consistent alignment with individual ovens,and requires an investigation into the dimensional variations of the battery. The equipment design must include allowance for these expected variations.

The battery growth was determined in a recent survey taken at P-4 battery and is compared with a similar one taken in 1965, and also the original plan. It can be seen that the buckstays at the top of the battery have been pushed outward from about 2 1/2" at the ends to as much as 7 11/16" at the center. In general the buckstays at the north end of battery (coal bin) tilt in that direction as much as 2 7/8" and those at the south end of battery tilt as much as 4 5/16". This can be seen in Figure 76.

A major consideration is to determine the location of the larry car tracks on the battery. On a new battery the tracks would be located within a specified tolerance. Limits must be established for allowable vertical and horizontal movement that would affect the position of the larry car with respect to the standpipe or charging holes. On an existing battery a survey must be made to determine the position. In most cases the rails would require shimming to provide a stable position from which to make any alignment adjustments. On P-4 battery the track elevation at the coal bin and at the opposite end was significantly higher than on the main body of ovens. The maximum variation in elevation was measured to be 1 3/8" on the coke side track and 1 1/2" on the pusher side track. The deviation of rails from a longitudinal centerline (length of battery) was ± 7/8" on the pusher side and ± 9/16" on the coke side. One bowed section of rail was replaced to reduce the variation. The rails were shimmed to minimize the vertical movement. This was also necessary to prevent spalling of brick under the rail chairs. The shims had a tendency to move, and required re-work to keep in place.

A survey of the cross battery position of charging hole rings with respect to a longitudinal centerline indicated a band of 2.25" for #1 charging holes, 2.625" for #2, and 2.875" for #3. The longitudinal variation of the three charging hole rings with

BATTERY DIMENSIONS (PART I)

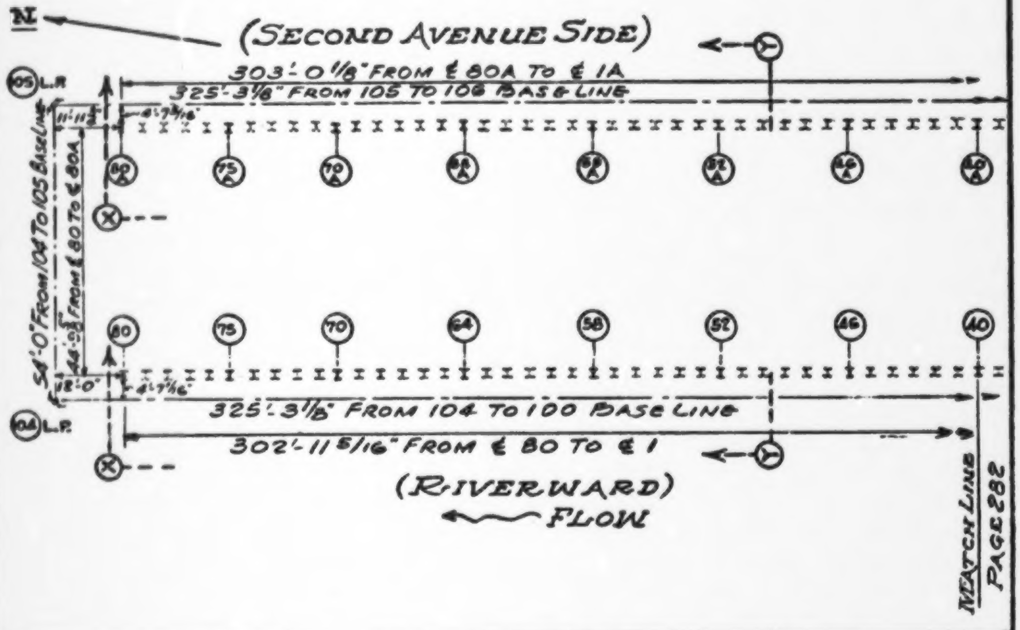

N
(SECOND AVENUE SIDE)
303'-0 1/8" FROM ℄ 80A TO ℄ 1A
325'-3 1/8" FROM 105 TO 106 BASE LINE
105 L.P.
54'-0" FROM 104 TO 105 BASE LINE
46'-9 3/8" FROM ℄ 80 TO ℄ 80A
80A
75A
70A
64A
58A
52A
46A
40A
80
75
70
64
58
52
46
40
12'-0"
325'-3 1/8" FROM 104 TO 100 BASE LINE
104 L.P.
302'-11 5/16" FROM ℄ 80 TO ℄ 1
(RIVERWARD)
FLOW
MATCH LINE PAGE 282

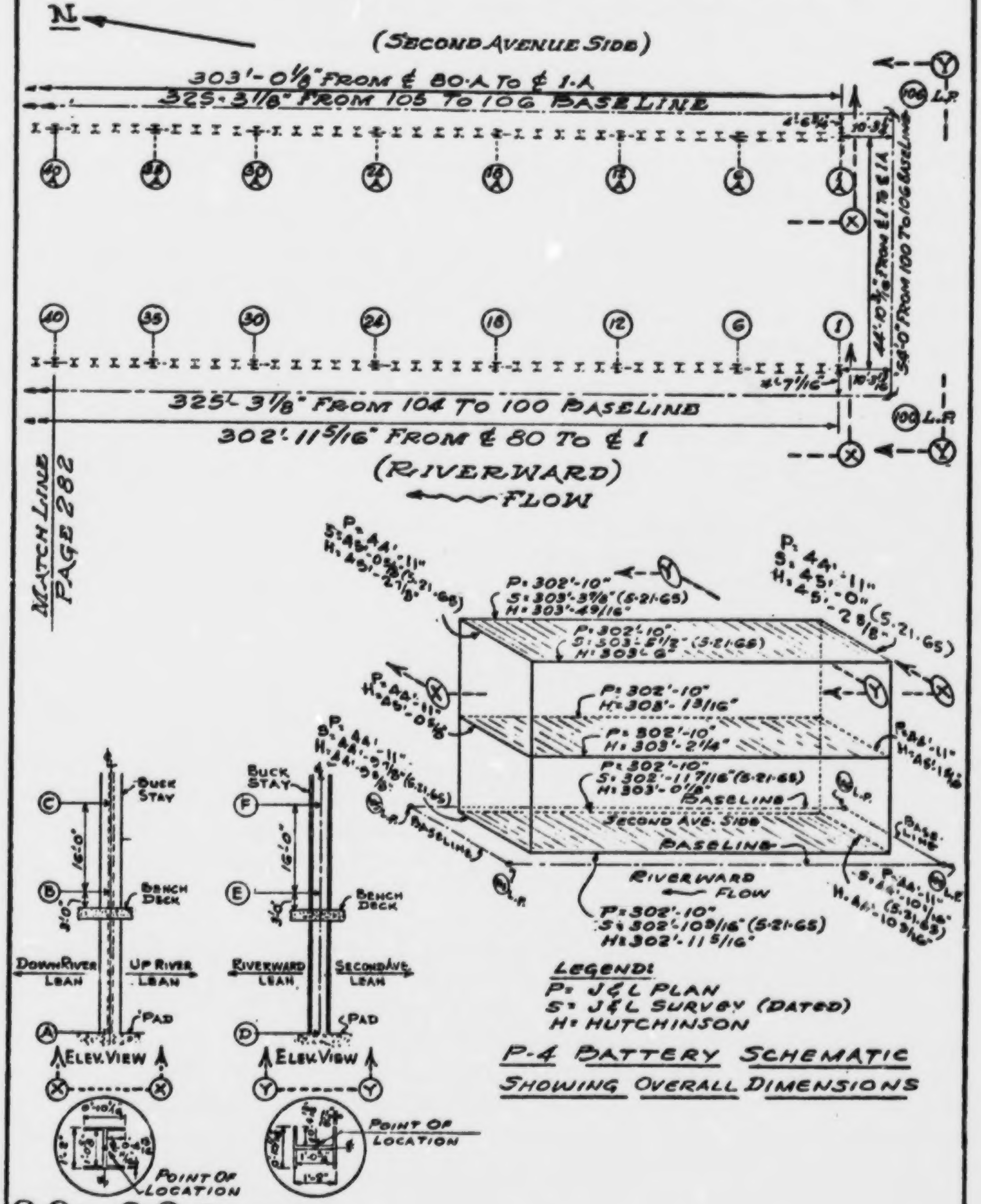
CHART SHOWING LEAN

	BUCK STAY No.	U: UPRIVER LEAN D: DOWNRIVER LEAN (A)	(B)	(C)	R: RIVERWARD LEAN S: SECOND AVE LEAN (D)	(E)	(F)
RIVERWARD BUCK STAYS	80	0	Do'-1 3/16"	Do'-2 3/8"	0	Ro'-1 13/16"	Ro'-2 3/8"
	75	0	Do'-0 13/16"	Do'-2 1/16"	0	Ro'-2 1/16"	Ro'-5 5/8"
	70	0	Do'-0 15/16"	Do'-1 11/16"	0	Ro'-2 1/2"	Ro'-7 9/16"
	64	0	Uo'-0 1/4"	Uo'-0 1/4"	0	Ro'-2 1/2"	Ro'-5 1/2"
	58	0	0	Do'-0 1/4"	0	Ro'-2 3/4"	Ro'-6 13/16"
	52	0	Do'-0 1/8"	Do'-0 1/8"	0	Ro'-2 1/4"	Ro'-5 3/8"
	46	0	0	Uo'-0 3/4"	0	Ro'-3 1/8"	Ro'-6 5/8"
	40	0	0	0	0	Ro'-3 1/2"	Ro'-7 11/16"
	35	0	0	Uo'-0 1/8"	0	Ro'-3 3/8"	Ro'-7 7/16"
	30	0	0	Uo'-0 5/8"	0	Ro'-3 1/4"	Ro'-6 3/8"
	24	0	Uo'-0 1/8"	Uo'-0 3/8"	0	Ro'-3 1/2"	Ro'-6 5/8"
	18	0	Do'-0 1/8"	Uo'-1 1/16"	0	Ro'-2 5/8"	Ro'-5 5/8"
	12	0	Uo'-0 1/4"	Uo'-1 3/16"	0	Ro'-2 5/8"	Ro'-5 1/2"
	6	0	Uo'-0 1/2"	Uo'-2 5/8"	0	Ro'-3 1/8"	Ro'-6 1/2"
	1	0	Uo'-1 13/16"	Uo'-4 5/16"	0	Ro'-2 1/4"	Ro'-2 3/16"

	BUCK STAY No.	U: UPRIVER LEAN D: DOWNRIVER LEAN (A)	(B)	(C)	R: RIVERWARD LEAN S: SECOND AVE. LEAN (D)	(E)	(F)
SECOND AVE. BUCK STAYS	80A	0	Do'-0 1/2"	Do'-2 3/8"	0	So'-1 3/16"	So'-2 7/8"
	75A	0	Do'-0 1/2"	Do'-1 15/16"	0	So'-1 11/16"	So'-4 5/16"
	70A	0	Do'-0 1/8"	Do'-1 7/16"	0	So'-1 11/16"	So'-5 1/16"
	64A	0	Do'-0 3/8"	Do'-1 3/16"	0	So'-1 9/16"	So'-4 5/16"
	58A	0	Do'-0 1/4"	Do'-1 5/16"	0	So'-1 11/16"	So'-5 1/4"
	52A	0	Do'-0 5/8"	Do'-1 11/16"	0	So'-1 11/16"	So'-4 11/16"
	46A	0	Do'-0 1/8"	Do'-0 15/16"	0	So'-1 15/16"	So'-5 7/8"
	40A	0	Do'-0 1/8"	0	0	So'-2 1/4"	So'-5 7/8"
	35A	0	0	0	0	So'-2 5/8"	So'-6 1/8"
	30A	0	Do'-0 1/4"	Uo'-0 1/2"	0	So'-1 11/16"	So'-4 15/16"
	24A	0	Do'-0 1/4"	Uo'-0 15/16"	0	Sd-1 13/16"	So'-4 9/16"
	18A	0	Do'-0 1/8"	Uo'-0 13/16"	0	So'-1 11/16"	So'-4 5/16"
	12A	0	Uo'-0 1/4"	Uo'-1 1/16"	0	So'-1 7/16"	So'-3 13/16"
	6A	0	0	Uo'-2 1/4"	0	So'-1 1/16"	So'-3 15/16"
	1A	0	Uo'-0 5/8"	Uo'-2 1/16"	0	So'-0 5/16"	So'-2 1/4"

Figure 76 (PT. I)

BATTERY DIMENSIONS (PART 2)


N
(SECOND AVENUE SIDE)
303'-0 1/8" FROM ℄ 80-A TO ℄ 1-A
325-3 1/8" FROM 105 TO 106 BASELINE
4'-6 3/4"
10-3 1/2
44'-10 3/4" FROM ℄ 1 TO ℄ 1A
54'-0" FROM 100 TO 106 BASELINE
106 L.P.
4'-7 1/16"
10-3 1/2
100 L.P.
40
35
30
24
18
12
6
1
325'-3 1/8" FROM 104 TO 100 BASELINE
302'-11 5/16" FROM ℄ 80 TO ℄ 1
(RIVERWARD)
FLOW
MATCH LINE PAGE 282
P: 302'-10"
S: 303'-3 7/8" (5-21-65)
H: 303'-4 9/16"
P: 302'-10"
S: 303'-5 1/2" (5-21-65)
H: 303'-6"
P: 302'-10"
H: 303'-1 3/16"
P: 302'-10"
H: 303'-2 1/4"
P: 302'-10"
S: 302'-11 7/16" (5-21-65)
H: 303'-0 1/8"
BASELINE
SECOND AVE. SIDE
BASELINE
RIVERWARD
FLOW
P: 302'-10"
S: 302'-10 9/16" (5-21-65)
H: 302'-11 5/16"
P: 44'-11"
S: 45'-0 3/8" (5-21-65)
H: 45'-2 1/8"
P: 44'-11"
S: 45'-0" (5-21-65)
H: 45'-2 5/8"
P: 44'-11"
H: 45'-0 5/8"
P: 44'-11"
S: 44'-9 7/8" (5-21-65)
H: 44'-9 5/8"
P: 45'-11"
H: 45'-1 5/8"
P: 44'-11"
S: 44'-10 1/16" (5-21-65)
H: 44'-10 3/16"
BASELINE
BASELINE
L.P.
L.P.
L.P.
L.P.
LEGEND:
P: J&L PLAN
S: J&L SURVEY (DATED)
H: HUTCHINSON
P-4 BATTERY SCHEMATIC SHOWING OVERALL DIMENSIONS
BUCK STAY
C
B
A
16'-0"
3'-0"
BENCH DECK
DOWN RIVER LEAN
UP RIVER LEAN
PAD
ELEV. VIEW
X
X
BUCK STAY
F
E
D
16'-0"
3'-0"
BENCH DECK
RIVERWARD LEAN
SECOND AVE. LEAN
PAD
ELEV. VIEW
Y
Y
POINT OF LOCATION
POINT OF LOCATION

⊗-⊗ AND Ⓨ-Ⓨ SECTIONS CHART MEASUREMENTS TAKEN WHERE SHOWN

Figure 76 (Pt. 2)

respect to an oven centerline (cross battery) was a band of 2.375" with the average being 1.054". This meant that in some cases the misalignment of charging holes for an individual oven exceeded 2". When referenced to the position of the gooseneck inspection port two ovens away the deviation could be considerably greater. The alignment of charging hole rings was limited by the amount of exposed charging hole brick work and the exposure of the charging hole ring to flame.

The position of the gooseneck inspection port with respect to an oven reference point varied in an unpredictable manner. The gas collecting main is divided into two independent sections. The growth of battery across the width pushed out the buckstays which support the collecting main. The expansion of the buckstay along the battery did not necessarily match the battery growth in that direction at all points. A history of some local hot spots in the collecting main resulted in its distortion at some points. The net result is that stand pipes lean in all directions, and the location of the gooseneck inspection port is unpredictable. There is little that can be done to correct this situation, and the equipment must be designed to operate under this set of conditions.

A survey was made along the battery of the position of the gooseneck port from the top of the larry car rail. The change in elevation varied over a band of 3 3/4" while the lateral measurements had a variable range of 4". Any movement of the rail could add to this variation. With accurate positioning of the larry car (± 1/2"), the variation of 2 ovens widths along the battery with respect to the gooseneck port provided a band of 3 1/2".

The type of dimensional variations that occur on a battery place a severe constraint on the design of operating equipment which depends on the positional relationship of the larry car to the battery. The installation of such equipment is very difficult on an existing battery, and should be avoided if not necessary. The incorporation of this type of equipment on new batteries should be done with care knowing the type of variations that can occur in future years.

APPENDIX G

ASCENSION PIPE PARTICULATE SAMPLING

A key part of the charging system involves the use of an ascension pipe steam ejector system that is capable of delivering a volume of gas equal to that being generated and displaced during charging. The increased volume of gas through the ascension pipe during charging results from a greater quantity of steam ejected into the gooseneck. The increased steam was obtained by increasing the steam nozzle from 1/2" to 3/4", increasing the steam header pressure from 100 psi to 175 psi, and increasing the diameter of the branch piping from 3/4" to 1 1/4".

Since other coke oven batteries, that use high pressure steam, have reported an increase in coal carried into the gas collecting main, tests were started to determine the magnitude of this problem. Ammonia liquor samples were collected at the bottom of the gas collecting main, just downstream from the oven where evaluation is desired. This is a coarse method of measurement; however by direct comparison with different ovens, some tentative conclusions were made. Some samples made near oven 3-18 (high pressure steam, 3/4" nozzle) indicated an increase in coal carry-over by a factor of five to ten when compared to the results from ovens using low pressure steam.

As a result of these tests a pressure regulator was added to the design of the new high pressure steam supply. This would permit regulating the pressure at a value less than 175 psi to prevent excessive coal carry-over.

Further tests were made to obtain more definitive results by taking measurements directly in the ascension pipes. As a starting point velocity and temperature of the ascension pipe gas were measured. The velocity of gas was determined from measurements taken with a pitot tube and water manometer. The pitot tube transmits the static pressure to one side of the manometer, and the dynamic pressure to the other side. The velocity is then proportional to the square root of the inches of water differential. The annubar is a self averaging pitot tube which eliminates the need to traverse while taking measurements. The results of the two methods checked within 15% giving confidence in the measurements.

ASCENSION PIPE PARTICULATE SAMPLING (continued)

Tests were then made to sample the coal carry-over. The annubar measured the differential pressure so that the gas flow rate could be calculated using the equation:

$Qn = 7.9\ SND^2\sqrt{\frac{r_f}{r_l}}\sqrt{h_h}$ (Refer to part A for details of equation)

Coal samples were collected in an Alundum filter contained in a sampling tube inserted in the ascension pipe. A thermocouple was used to measure the gas temperature. The complete test procedure is described in Part B. Sample calculations are shown in Part C.

The quantitative evaluation of coal carry-over is subject to error and the calculations represent an upper limiting value that was probably never reached. The material from which the ash is derived represents various carbonaceous material from coal to coke. The ash content of coke and semi-coke materials is higher than that of coal thus causing higher results. Factors during leveling such as the way in which the gas passageway is constricted as well as the degree of port seals (particularly the leveler door opening) are expected to influence the amount of coal carry-over.

The results of this investigation indicated that the coal carry-over during charging increased by a factor of about 6:1 for the high pressure steam. This comparison was based on six tests.

A more accurate method of determining the amount of coal carry-over involved taking tar samples from the #9 cross-over of P-4 battery with the aspirating steam header pressure at 130 psi and then 180 psi. These tar samples were collected in a 55 gallon drum in such a manner that the excess flushing liquor was drained off to the decanters. The tar samples were taken just prior to the point where the tar mixes with that of other batteries before reaching the decanter. The analysis of the tar from each sample is shown in Table 6 (pg 95).

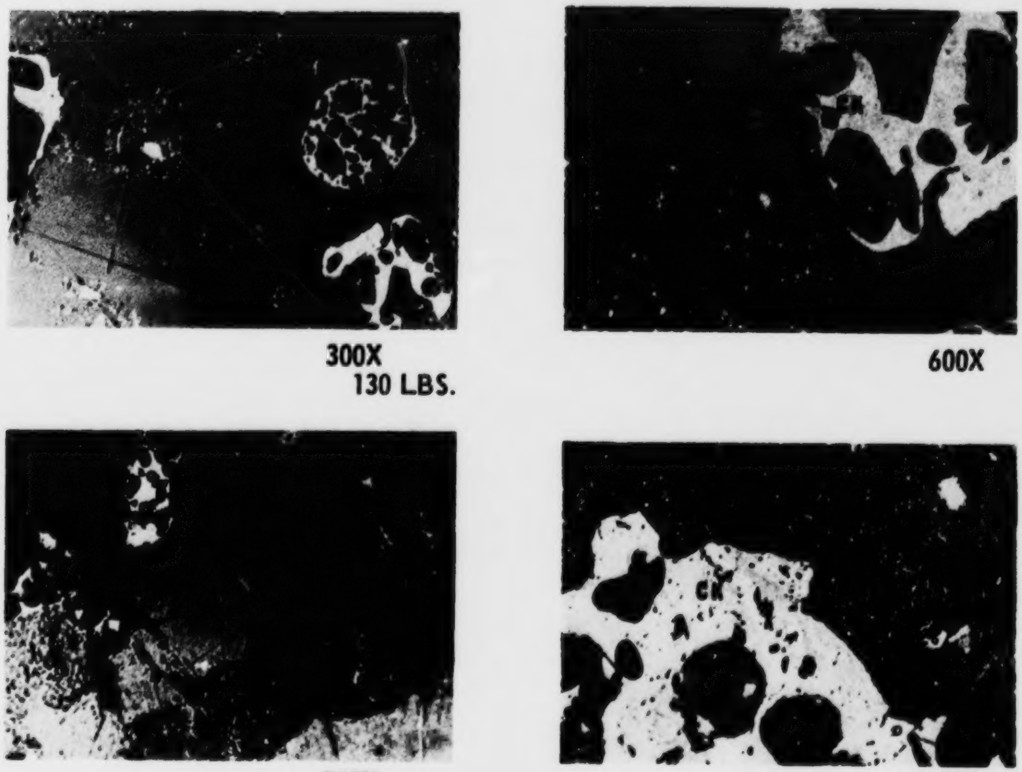
A microscopic analysis of the suspended solids was made by repeatedly washing the tarwith xylene. The filtered solids were dried, imbedded in an epoxy resin and polished. Microscopic examination of the polished specimens revealed that suspended

ASCENSION PIPE PARTICULATE SAMPLING (continued)

solids consisted of very fine spherulitic carbon particles, coal, semi-coke, coke, and pyrolytic carbon (similar to wall and roof carbon), as shown in figure 77. The spherulite carbon is derived from the cracking or incomplete combustion of gases, whereas the coal and coke are derived from the oven charge. The distribution of the carbon forms was determined and adjusted to the percent of quinoline insolubles in the tars. These values, shown in Table 28, indicate that the tar collected at higher steam pressure had more and larger carbon solids derived from coal carbonization.

Based on a value of 7 gallons of tar (from flushing liquor) and 16.7 tons of coal per charge, a specific gravity of 1.20, approximately 22.1 pounds of coal carry-over per charge occurs at 130 psi while the value at 180 psi was about 49 pounds of coal. This represents a lower limit, since some of the coal would settle out in the collecting main.

PHOTOMICROGRAPHS - SUSPENDED SOLIDS IN TAR



300X
130 LBS.

600X

300X
180 LBS.

300X

PHOTOMICROGRAPHS SHOW SPHERULITIC CARBON (SC), COAL (C), COKE (CK) OBTAINED FROM PITTSBURGH TAR COLLECTED WHILE P-4 BATTERY OPERATED WITH INDICATED STEAM ASPIRATING PRESSURE. BLACK AREAS ARE PORES AND GRAY AREAS ARE PLASTIC IMBEDDING MATERIAL (PL). REFLECTED LIGHT.

FIGURE 77

Table 28. DISTRIBUTION AND SIZE OF SUSPENDED SOLIDS IN TAR
(Varible steam pressure)

	Wt.,% of Total Tar[1] Steam Pressure, lbs.		Header Steam Pressure, psi			
			130		180	
	130 (Base)	180 (Trial)	Microns	Tyler Mesh	Microns	Tyler Mesh
Spherulitic Carbon	6.1	4.8	6	400	6	400
Coal	0.2	0.8	230	60-70	430	35-40
Semi-coke	0.2	1.1	90	140-170	350	40-45
Coke	1.7	3.9	220	60-70	430	35-40
Pyrolytic Carbon	0.3	1.3	230	60-70	460	35-40
Quinoline Insolubles in tar, (wt.,%), determined by chemical analysis (wt. %)	8.5	11.9				

[1] Adjusted to quinoline insoluble content

PART A

GAS FLOW EQUATION

The equation used to determine gas velocity from the differential pressure measurements appears in the Annubar Technical Data, Section C of the Ellison Instrument Division catalog under the title "Annubar Flow Calculation Report".

$$Qn = 7.9\ SND^2\ \frac{\sqrt{r_f}}{r_1}\ \sqrt{h_n}$$

Since r_f is related to r_1 this relation is reduced to:

$$Qn = 7.9\ SND^2\ \frac{\sqrt{\frac{14.7 + \text{PSIG of line}}{14.7} \times \frac{520}{460 + \text{line temp } (^{\circ}F)}}}{\sqrt{r_1}}\ \sqrt{h_n}$$

The line pressure never exceeds a few inches of water, consequently

$$\frac{14.7 + \text{PSIG of line}}{14.7} \approx 1$$

$$\therefore Qn = 7.9\ SND^2\ \frac{\sqrt{\frac{520}{460 + \text{line temp } (^{\circ}F)}}}{\sqrt{r_1}}\ \sqrt{h_n}$$

S= Constant factor for element at specific flow,
= Kg Fv

KG= geometrical constant; for element type 740 and 13" pipe, Kg = 0.913

Fv= velocity distribution factor; for transition and turbulent flow, Fv = 0.82

S= Kg Fv = (0.913)(0.82) = 0.75

N= grouped constant including $\sqrt{2g}$ (gravity acceleration, $\pi/4$ (circular area), and conversion constants which depend on units chosen for Qn and h_n.

GAS FLOW EQUATION (continued)

Where Qn is expressed in CFM, and h_n is expressed in inches of H_2O corrected to 68°F.

N= 0.7576

D= exact inside diameter of pipe (inches)

r_1= specific weight of gas at base conditions in pounds per cubic foot. This is also equal to the specific gravity of gas at base conditions times the weight of air (#/ft^3) at base conditions. Air = 0.0765 #/ft^3 at standard (60°F/ 14.73 psia) base conditions.

A value of 0.7 has been used for the specific gravity based on approximate results using Schillings apparatus.

r_f= specific weight at flowing conditions in pounds per cubic foot including compressibility.

$$r_f = \frac{14.7 + \text{PSIG line}}{14.7} \times \frac{520}{460 + \text{line temp. } (^\circ F)} \times r_1$$

For this application

$$7.9\ SND^2 = 7.9 \times 0.75 \times 0.7576 \times (13)^2$$
$$= 759$$

$$\therefore Qn = 759 \qquad \sqrt{\frac{\frac{520}{460 + T\text{ line}}}{\sqrt{r_1}}} \qquad \sqrt{h_n}$$

Let $r_1 = 0.7 \times 0.0765 = 0.0535$

$$\sqrt{r_1} = \sqrt{0.0535} = 0.231$$

$$Qn = 3280 \sqrt{\frac{520}{460 + T\text{ line}}} \times \sqrt{h_n}$$

GAS FLOW EQUATION (continued)

This equation can now be used to measure ascension pipe gas flow (Q_n) in CFM by determining the temperature of gas within the ascension pipe and the differential pressure. The effective specific gravity of the gas must also be determined with reasonable accuracy.

PART B

TEST PROCEDURE

Equipment requirements are as follows:

1. 1 - Annubar
2. 1 - Alundum filter holder and sampling tube
3. 1 - Alundum filter for each test
4. 1 - H_2O filled manometer 36"
5. 1 - Hg filled manometer 36"
6. 1 - Thermometer 0^oF to 250^oF
7. 1 - Thermocouple and wire
8. 1 - Potentiometer
9. 1 - Gas volume meter
10. 1 - Air aspirator
11. Assorted stainless steel and copper tubing with fittings
12. 1 - 3" pipe 2' long threaded one end.

Procedure

The tubing is cut to length and assembled with fittings. One 1" hole is drilled and one 3" hole is drilled half way up in each of the ascension pipes standpipes with the former hole being 3" above the latter hole. A 1" sleeve and a 3" sleeve are welded to the standpipe to enable the holes to be plugged and the instruments to be supported.

The instruments are assembled according to Figures78, and 79.

The test is conducted for the first 60 to 70 seconds after the start of leveling. The air aspirator is turned on as soon as leveling starts, and readings are taken continuously by a four

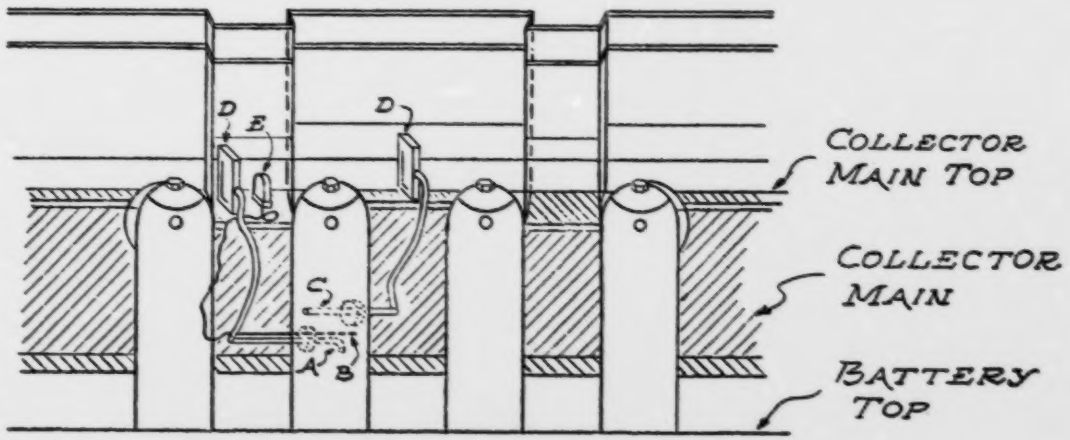
TEST PROCEDURE (continued

Procedure (continued)

man crew for 60 to 70 seconds. One man each is required to read the annubar's manometer; gas meter's manometer, thermometer and gauges; the thermocouple's poteniometer; and to time with a stopwatch. After the test, the collected sample is taken to the chemical lab where an analysis is made of the collected particulate to determine the amount of suspended solids. This analysis consists of weighing the particulate (to determine the total weight), rinsing with benzene and re-weighing (to determine the percentage of tar), and burning the sample and weighing again (to determine the percentage of ash).

The data collected during a test is used to calculate the rate of flow in SCFM and the amount of coal carryover per standard cubic foot. This data are then used to calculate the ratio of coal carryover with the high pressure steam versus coal carryover with the low pressure steam.

ASCENSION PIPE COAL CARRY-OVER SAMPLING


D
E
D
C
A
B
COLLECTOR MAIN TOP
COLLECTOR MAIN
BATTERY TOP

A - PILOT TUBE IN INITIAL TESTS OR SAMPLING TUBE IN FINAL TESTS.
B - THERMOCOUPLE
C - ANNABAR
D - MANOMETER
E - POTENTIOMETER

Figure 78

COAL SAMPLING APPARATUS

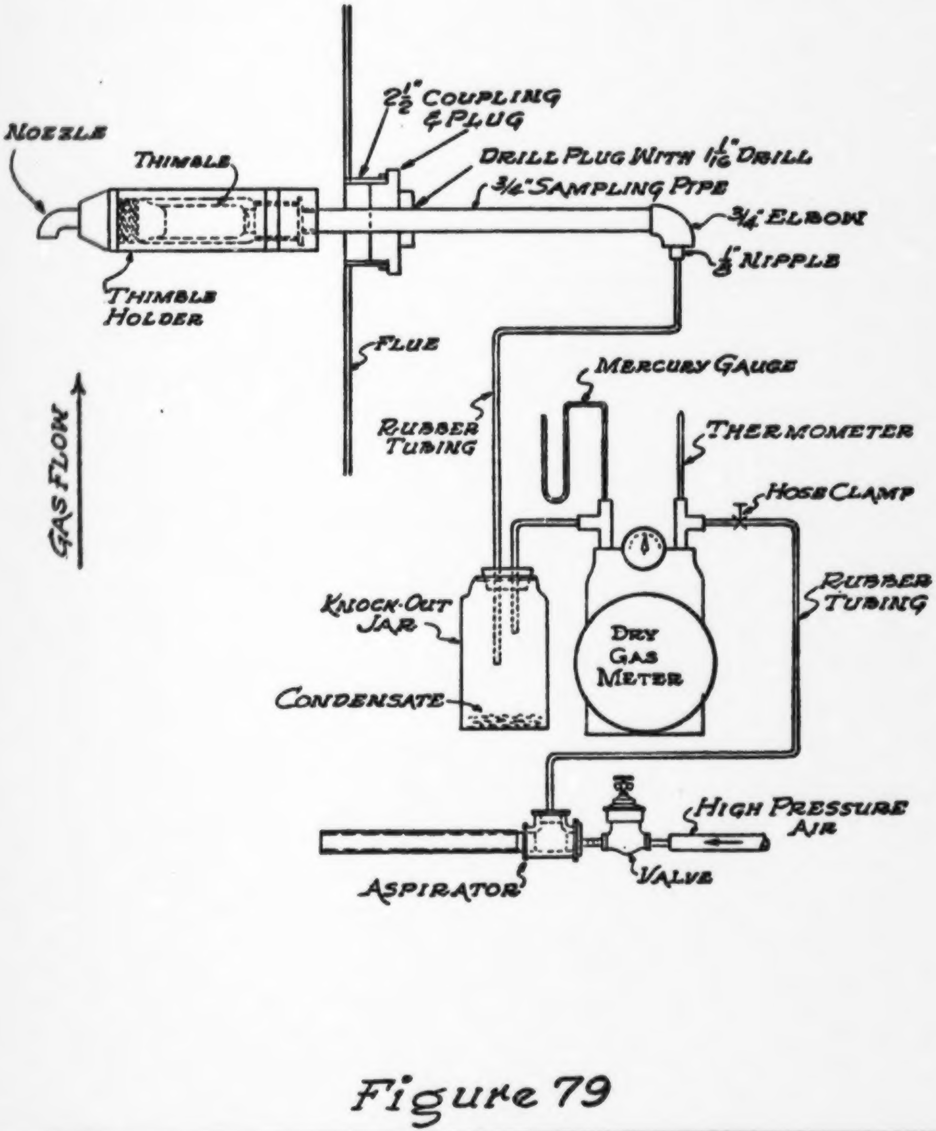

NOZZLE
THIMBLE
THIMBLE HOLDER
2½" COUPLING & PLUG
DRILL PLUG WITH 1/16" DRILL
¾" SAMPLING PIPE
¾" ELBOW
⅛" NIPPLE
FLUE
GAS FLOW
MERCURY GAUGE
RUBBER TUBING
THERMOMETER
HOSE CLAMP
RUBBER TUBING
KNOCK-OUT JAR
CONDENSATE
DRY GAS METER
HIGH PRESSURE AIR
ASPIRATOR
VALVE

Figure 79

PART C

SAMPLE CALCULATIONS

Attached are the data sheets from six tests made on two different dates. The calculated gas velocity in the standpipe is determined with the following equation,

$$Qn = 3280 \sqrt{\frac{520}{460 + T\ \text{line}}} \times \sqrt{h_n}$$

The calculated volume of the metered gas sample is,

$$\text{Std. Cubic Feet} = \text{Vol.} \times \left(\frac{460 + 68}{460 + T}\right) \left(\frac{30 + P}{30}\right)$$

The re-calculated sample weight is,

$$\text{Coal Weight} = \text{sample wt.} \times \left(\frac{\%\ \text{Coal ash in sample}}{\%\ \text{Coal ash in charged coal}}\right)$$

The estimated coal carry-over per charge is,

$$\text{Pounds coal/charge} = \frac{\text{Grams coal}}{\text{Ft}^3} \times \frac{\text{Pounds}}{\text{Gram}} \times \text{Qn avg.} \times \begin{array}{l}\text{Average}\\ \text{Charge}\\ \text{Time}\end{array}$$

Test Data Summary Sheet

Test No. Date Oven No.	1 9/6 3-24	2 9/6 3-13	3 9/13 3-18	4 9/13 3-13
Calculated Gas Velocity				
T line (^oF)	2129	1453	1936	1993
h_n ('' H_2O)	2.3	0.676	2.1	0.45
Q_n (Eq. 1)	2220 CFM	1410 CFM	2220 CFM	1020 CFM
Calculated Metered Gas Sample				
Sample Vol. (Ft^3)	0.5	.45	0.3	0.33
Gas Temp. at gas meter (^oF)	90	118	110	80
Gas Pressure at gas meter ('' Hg)	-15"	-13.4"	-16"	-15"
Sample Vol. in Std. cubic feet	0.24	0.228	0.13	0.161
Recalculated Sample Weight				
Sample Weight (g.)	3.2	1.04	2.8	2.01
% Coal Ash in Sample	14.3	12.8	18.4	13.5
% Coal Ash in Charged Coal	7.85	7.85	7.84	7.84
Recalculated Sample Wt. (g.)	5.82	1.7	6.58	3.46
Grams Coal Ft^3 Gas	24.2	7.45	50.6	21.5
Pounds Coal Charging Cycle	237	46.3	495	96

Test Data Summary Sheet

Test No.	5	6		
Date	9/13	9/13		
Oven No.	3-24	3-11		
Calculated Gas Velocity				
T line (°F)	1949	1895		
h_n ("H_2O)	2.4	.4		
Q_n (Eq. 1)	2360 CFM	975 CFM		
Calculated Metered Gas Sample				
Sample Vol. (Ft^3)	.21	.3		
Gas Temp. at gas meter (°F)	78	90		
Gas Pressure at gas meter (" Hg)	-15	-15		
Sample Vol. in Std. cubic feet	.103	.144		
Recalculated Sample Weight				
Sample Weight (g.)	3.2	.81		
% Coal Ash in Sample	19.2	20.3		
% Coal Ash in Charged Coal	7.84	7.84		
Recalculated Sample Wt. (g.)	7.85	2.1		
Grams Coal Ft^3 Gas	76.2	14.6		
Pounds Coal Charging Cycle	795	62.8		

ASCENSION PIPE GAS SAMPLING DATA SHEET TEST 1

Date September 6, 1971 **Oven No.** 3-24 **Time** 65 Seconds

Condition at Start of Time Start of leveling

Reading	**Time**	**Annubar ΔP (" H_2O)**	**Thermocouple Temp. (^{o}F)**	**Calculated Gas Velocity**
1	30 seconds	2.3"	2129°	2220 SCFM
2				
3	NOTE:	Other readings during this test were not properly recorded and were discarded. This one valid reading appears to be representative of the average.		
4				
5				
6				

Gas Sample Meter Data

Measured Pressure (" Hg)	-15"
Measured Temperature (^{o}F)	90°
Metered Gas Sample (Ft^3)	.5 ft^3
Timed Gas Sample Period (Sec.)	65 sec.
Calculated Metered Gas (Std. Cond.)	.24 SCF

Particulate Sample

Sample Weight 3.2 grams

% Benzene Insol Fraction 98.2% **% Ash** 14.3%

Recalculated Sample Weight 5,82

Calculated $\frac{\text{Grams Coal}}{\text{Ft}^3\text{ Gas}}$ 24.2

Sampling Condition

Coal Ash	7.85%
Coal Pulverization	75.8% thru 1/8" screen
Coal Moisture	6.5%
Qts. Oil/Ton Coal	3.55
Header Steam Pressure	175 psi
Ascension Pipe I. D.	13"

ASCENSION PIPE GAS SAMPLING DATA SHEET TEST 2

Date September 6, 1971 Oven No. 3-13 Time 67 seconds

Condition at Start of Time Start of leveling

Reading	Time	Annubar ΔP (" H_2O)	Thermocouple Temp. (^oF)	Calculated Gas Velocity
1	0 second	.95"	1478	
2	12 seconds	..90"	1226	
3	24 seconds	.65"	1626	
4	36 seconds	.53"	1512	
5	48 seconds	.6"	1556	
6	60 seconds	.7"	1346	
	Average	.676"	1455	1410 SCFM

Gas Sample Meter Data

Measured Pressure (" Hg) -13.4"

Measured Temperature (^oF) 118^oF

Metered Gas Sample (Ft^3) .45 ft^3

Timed Gas Sample Period (Sec.) 67 sec

Calculated Metered Gas (Std. Cond.) .228 ft^3

Particulate Sample

Sample Weight 1.04 grams

% Benzene Insol Fraction 99.1% % Ash 12.8%

Recalculated Sample Weight 1.7

Calculated $\frac{\text{Grams Coal}}{\text{Ft}^3\text{ Gas}}$ 7,45 g/ft^3

Sampling Condition

Coal Ash 7.85%

Coal Pulverization 75.8 thru 1/8" screen

Coal Moisture 6.5%

Qts. Oil/Ton Coal 3.55

Header Steam Pressure 100 psi

Ascension Pipe I. D. 13"

ASCENSION PIPE GAS SAMPLING DATA SHEET TEST 3

Date September 13, 1971 **Oven No.** 3-18 **Time** 67 seconds

Condition at Start of Time Start of leveling

Reading	Time	Annubar ΔP ('' H_2O)	Thermocouple Temp. (^oF)	Calculated Gas Velocity
1	0 second	.8''	1690	
2	20 seconds	2.2''	2208	
3	40 seconds	2.4''	1827	
4	60 seconds	1.6''	1772	
5	Average	2.1''	1936	2220 SCFM
6				

Gas Sample Meter Data

Measured Pressure ('' Hg)	-16
Measured Temperature (^oF)	110°
Metered Gas Sample (Ft^3)	.3 cu. ft.
Timed Gas Sample Period (Sec.)	67 sec.
Calculated Metered Gas (Std. Cond.)	.130

Particulate Sample

Sample Weight 2.8 grams

% Benzene Insol Fraction 99.4 % Ash 18.4

Recalculated Sample Weight 6.58

Calculated $\frac{\text{Grams Coal}}{\text{Ft}^3\ \text{Gas}}$ 50.6

Sampling Condition

Coal Ash	7.84%
Coal Pulverization	74.1% thru 1/8'' screen
Coal Moisture	6.60%
Qts. Oil/Ton Coal	3.03
Header Steam Pressure	175 psi
Ascension Pipe I.D.	13''

ASCENSION PIPE GAS SAMPLING DATA SHEET TEST 4

Date September 13, 1971 **Oven No.** 3-13 **Time** 73 Seconds

Condition at Start of Time Start of leveling

Reading	Time	Annubar ΔP ('' H_2O)	Thermocouple Temp. (^{o}F)	Calculated Gas Velocity
1	0 second	.6	972	
2	20 seconds	.6	1986	
3	40 seconds	.4	1995	
4	60 seconds	.4	1995	
5	73 seconds	.4	1995	
6	Average	.45	1993	1020 SCFM

Gas Sample Meter Data

Measured Pressure ('' Hg) -15''

Measured Temperature (^{o}F) 80°

Metered Gas Sample (Ft^3) .33

Timed Gas Sample Period (Sec.) 73 sec.

Calculated Metered Gas (Std. Cond.) .161 SCF

Particulate Sample

Sample Weight 2.01 grams

% Benzene Insol Fraction 98.3 **% Ash** 13.5

Recalculated Sample Weight 3.46

Calculated $\frac{\text{Grams Coal}}{\text{Ft}^3 \text{ Gas}}$ 21.5

Sampling Condition **Coal Ash** 7.84%

Coal Pulverization 74.1 % thru 1/8'' screen

Coal Moisture 6.60%

Qts. Oil/Ton Coal 3.03

Header Steam Pressure 100 psi

Ascension Pipe I. D. 13''

ASCENSION PIPE GAS SAMPLING DATA SHEET

TEST 5

Date September 13, 1971 **Oven No.** 3-24 **Time** 67 Seconds

Condition at Start of Time Start of leveling

Reading	**Time**	**Annubar ΔP (" H_2O)**	**Thermocouple Temp. (^oF)**	**Calculated Gas Velocity**
1	0 second	3.0	1329	
2	15 seconds	2.0	1591	
3	30 seconds	2.5	2150	
4	45 seconds	2.5	2244	
5	60 seconds	2.5	1811	
6	Average	2.4	1949	2360 SCFM

Gas Sample Meter Data

Measured Pressure (" Hg)	-15
Measured Temperature (^oF)	78
Metered Gas Sample (Ft^3)	.21
Timed Gas Sample Period (Sec.)	67
Calculated Metered Gas (Std. Cond.)	0.103 SCF

Particulate Sample

Sample Weight 3.2 grams

% Benzene Insol Fraction 99.2 **% Ash** 19.2

Recalculated Sample Weight 7.85 grams

Calculated	$\frac{\text{Grams Coal}}{\text{Ft}^3 \text{ Gas}}$	76.2

Sampling Condition

Coal Ash	7.84%
Coal Pulverization	74.1% thru 1/8" screen
Coal Moisture	6.60%
Qts. Oil/Ton Coal	3.03
Header Steam Pressure	175 psi
Ascension Pipe I. D.	13"

ASCENSION PIPE GAS SAMPLING DATA SHEET TEST 6

Date September 13, 1971 **Oven No.** 3-11 **Time** 67 Seconds

Condition at Start of Time Start of leveling

Reading	Time	Annubar ΔP (" H_2O)	Thermocouple Temp. (^oF)	Calculated Gas Velocity
1	0 second	.6	1329	
2	20 seconds	.4	1957	
3	40 seconds	.4	1772	
4	60 seconds	.4	1957	
5	Average	.4	1895	975 SCFM
6				

Gas Sample Meter Data

Measured Pressure (" Hg)	-15
Measured Temperature (^oF)	90
Metered Gas Sample (Ft^3)	.3
Timed Gas Sample Period (Sec.)	67
Calculated Metered Gas (Std. Cond.)	0.144 SCF

Particulate Sample

Sample Weight 81 grams

% Benzene Insol Fraction 99.4 % Ash 20.3

Recalculated Sample Weight 2.1 grams

Calculated $\frac{\text{Grams Coal}}{\text{Ft}^3\ \text{Gas}}$ 14.6

Sampling Condition

Coal Ash	7.84%
Coal Pulverization	74.1% thru 1/8 screen
Coal Moisture	6.60%
Qts. Oil/Ton Coal	3.03
Header Steam Pressure	100 psi
Ascension Pipe I. D.	13"